2019 Rural Development Report

BACKGROUND PAPERS

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Rural transformation and the double burden of malnutrition among rural youth in low- and middle-income countries

by
Suneetha Kadiyala
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Chittur Srinivasan
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IFAD
Investing in rural people

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Giacomo Zanello has concentrated his work on efforts to understand how agriculture, food, nutrition and health interact in low- and middle-income countries. An economist by training, he is a lecturer in food economics and health at the University of Reading. Previously he supported the work of the Global Panel on Agriculture and Food Systems for Nutrition, and was a research officer at Oxford University's Department of International Development.

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Abstract

Adolescence and early adulthood are periods of major biological, economic and social transitions for rural youth. They provide a critical window of opportunity for addressing chronic nutritional deficits from childhood, for “catch-up” growth, for providing a solid foundation for a healthy productive and reproductive life, and for arresting the intergenerational transmission of malnutrition. In this study we show that rural transformation processes are associated with improvements in rural youth nutrition – malnutrition and underweight – in nearly all regions, although the pace of change varies considerably across countries. Most low- and middle-income countries (LMICs) are faced with the double burden of malnutrition and overweight/obesity, and in some countries this double burden is increasing, with the prevalence of underweight and overweight/obesity rising concurrently.

The effect of rural transformation processes on rural youth nutrition is mediated by its effects on the external and personal domains of the “food environment”. Transformation of agri-food systems are bringing about large changes in the diets of rural youth in LMICs, and particularly of the younger age groups, who appear to be witnessing rapid dietary transitions. The Young Lives dataset suggest that certain near-universal changes in patterns of dietary and nutrient intake patterns can be discerned in LMICs, although the pace of change varies. Dietary transitions are also driven by “globalisation influences” – especially dissemination of information through digital/social media and food industry advertising and marketing strategies – even in countries with low/slow rural transformation.

Our results show that rural transformation processes can have both positive and negative effects on rural youth nutrition in LMICs. Despite the globalisation influences of international trade and agri-food systems, dietary changes in individual LMICs are still influenced by national policies and production patterns. Understanding the pathways to impact of rural transformation on rural youth nutrition is crucial for designing “nutrition-sensitive” rural transformation policies.

1. Introduction

Good nutrition is foundational to human survival and development. The momentum to accelerate reductions in all forms of malnutrition – deficiencies, excesses or imbalances in a person's nutrition status – is now high on the international development agenda (WHO, 2012; 2013; United Nations General Assembly, 2016). Significant strides have been made in improving nutrition outcomes over recent decades, but malnutrition remains a large-scale problem.

Many low- and middle-income countries (LMICs) still face persistent nutritional deficiencies, such as undernutrition or gaps in key micronutrients such as iron. But several of them are also now experiencing escalating levels of diet-related chronic conditions such as overweight, obesity, cardiovascular disease and diabetes mellitus (Popkin, 2014; Popkin et al., 2001). Rapid dietary and lifestyle changes coupled with only slow improvements in tackling nutritional deficiencies has left many LMICs facing a "double burden of malnutrition" – a coexistence of undernutrition (macro- and micronutrient deficiencies), overweight/obesity and non-communicable diseases (Development Initiatives, 2017; Haddad et al., 2016). Low dietary quality is the top risk factor for the global burden of disease (Lozano et al., 2012).

While maternal and child undernutrition and rising diet-related chronic conditions among adults continue to receive much-needed attention, nutrition among young people is, after years of neglect, now firmly on the international health and development agendas (Bundy et al., 2017; Patton et al., 2016; WHO, 2005). Reduction in the prevalence of underweight among adolescent girls and boys has been patchy, but overweight and obesity has increased globally (Christian and Smith, 2018; Galloway, 2017). Anaemia is the leading cause of mortality among adolescent girls. In an analysis of 15 LMICs, one in five late-adolescent (15-19 years) boys are underweight (Galloway, 2017). Investing in youth nutrition is key to ensure long-term health outcomes, health expenditure savings later in life, preventing intergenerational transmission of malnutrition, as well as increased income and productivity over the life course (Knowles and Behrman, 2003; Patton et al., 2016). Investing in good nutrition in adolescence and young adulthood is critical to sustain rapidly transforming economies and reduce the burden on already strained health systems. The *Global Strategy for Women's, Children's and Adolescents' Health* for 2016-2030 (Every Woman Every Child, 2016) identifies adolescents as being central to achieving the Sustainable Development Goals. Remarkably, prioritization of youth features prominently in the 2030 Agenda for Sustainable Development adopted by the United Nations General Assembly (2015).

Young people's opportunities and risk factors for optimal nutrition are rapidly changing due to sweeping economic, technological, social and demographic transformations in the last two decades. A quarter of world's population in 2012 comprised young people (10-24 years); of these 90 per cent lived in LMICs (UNFPA, 2014). It is estimated that between 2010 and 2050 more than 15 million young women and men will be joining the work force each year, and a large majority of them will be employed in the rural informal sector (Vargas-Lundius and Suttie, 2014). Accordingly, the integration of surging rural youth in emerging economic and social transformations will shape LMICs' economic, nutritional and health outcomes, which are inextricably linked with changes in rural economies. Understanding the interconnections between rural transformations and young people's nutritional behaviours and outcomes is therefore critical in order to reap the demographic dividend stemming from young people (UNFPA, 2014).

Despite the critical importance of nutrition among youth, little is known about the nutritional behaviours and outcomes among youth in rural areas,[1] as most of the few existing studies have focused on dietary transition within urban centres (see Ochola and Masibo, 2014, for an excellent review). Even less is currently known about the way in which rural transformations are contributing to shape those outcomes and whether these are youth- and nutrition-sensitive (Vargas-Lundius and Suttie, 2014). This paper attempts to connect health and agriculture development agendas concerning youth in the context of structural and rural transformations.

The overarching aim of this paper is to examine how rural transformation processes contribute to changes in diets and nutrition status among rural youth in LMICs. Specifically, we describe the trends in rural transformation and emergence of the double burden of malnutrition, with a focus on thinness and overweight/obesity among young people at the macro level. Using the Young Lives (www.younglives.org.uk) dataset from four countries, we then examine the associations between some aspects of rural transformation, food-system-related changes and the double burden of malnutrition among young people.

Section 2 elaborates the unique features of adolescents and the importance of optimal nutrition during this life-stage. Section 3 presents a unifying conceptual framework elaborating the interconnections between structural and rural transformations, food systems and adolescent nutrition. Section 4 reviews the literature on trends in nutrition status of rural youth in LMICs. Section 5 presents the methodology of the paper. Section 6 describes the macro trends in rural transformations and body mass index (BMI)-based nutritional outcomes. Using the Young Lives panel data, Section 7 examines changes in nutritional status and diets among young people in India, Ethiopia, Peru and Viet Nam and seeks to assess the associations between indicators of rural transformation and food environments on nutritional outcomes among young people in these four countries. We conclude with policy recommendations in Section 8.

2. Importance of nutrition among youth

"Adolescents are not simply old children or young adults; they have particular needs." (WHO, 2017)

Much of the nutrition and health literature on youth or young people employs the term "adolescence". Like the definitions of youth, this strand of literature adopts a broad age definition for adolescence, categorized broadly as follows: early adolescence (10-14 years); mid-adolescence (15-19 years) and young adulthood (16-24 years). In this paper, we use the terms youth, young people and adolescents interchangeably.

Adolescents' health and nutrition outcomes are determined by an interaction of biological and social processes. As a result, it is also during adolescence that sex-differentiated mortality and morbidity patterns begin to emerge.

2.1 Biological processes: Growth and development

The growth and maturation of reproductive, musculoskeletal, neurodevelopmental, endocrine, metabolic, immune and cardio-metabolic systems initiated in early adolescence (puberty) underpin well-being throughout the life course.

[1] For instance, a recent reviews has provided novel evidence on the global state of adolescent nutritional outcomes, but only stratification by gender was included (Galloway, 2017). Our initial review did not reveal similar reviews focusing on youth and how changes in nutrition might be determined by rural transformation.

A second window of opportunity

While the "first 1,000 days" of a child's life (conception to 24 months) represents the optimal window of opportunity for child growth, adolescence represents another critical window to address stunting (defined as a height-for-age z-score below -2 standard deviations [SD]), an indicator of chronic nutritional deficits. Data from Brazil, India, Philippines, Guatemala, South Africa and Gambia shows that "catch-up" growth continued until early adulthood (Prentice et al., 2013); catch-up growth was the highest in countries with higher prevalence of malnutrition (Guatemala, Philippines and India). Moreover, the greatest height gain to adulthood was observed among children who were most stunted at 24 months. Nutritional resources to capitalize on this second window of opportunity for growth among young people, without exacerbating any potential adverse consequences such as overweight and obesity, can have a lasting impact on their current and future well-being. Their growth and development provide a foundation for the start to life of the next generation and arresting the intergenerational transmission of malnutrition (Bundy et al., 2017; Patton et al., 2018).How financial inclusion can contribute to the development challenge.

Brain development and neuro-cognitive maturity

The structure and function of the brain continue to change throughout adolescence. These neurodevelopment changes in adolescence do not start and end together: grey matter volume, which forms the structure of the brain, peaks in early childhood; the volume of white matter, which connects these structures, increases gradually into early adulthood (Galloway, 2017). Thus, regions of the brain that are involved with more complex and integrative tasks continue to develop throughout adolescence (Gogtay, 2004). The temporal cortex, which contains association areas that integrate information from several sensory modalities, matures until the early 20s.

As the most metabolically active organ, the brain's adequate balanced nutrition is essential for its development and for the proper maturation of the neural mechanisms. Macro- and micronutrient deprivation during the first 1,000 days leads to reduced brain size, activity and functionality (Galloway, 2017). Because of the brain's differential developmental trajectories from conception to the early 20s, optimal nutrition throughout this age-range is essential for subsequent outcomes.

The neurobiology of the brain is also influenced by environmental conditions such as poverty and life stress, which economic transformations influence substantially. Children from lower-socio-economic-strata environments differ in their grey matter accumulation in the frontal and parietal lobes, such that differences widen throughout development as the exposure to impoverished environments continues (NCD-RisC, 2017; Lozano et al., 2012). Developmental changes in stressor-sensitive regions of the brain (for example, dopamine systems) influence risk-taking and novelty-seeking behaviours (Spear, 2000) which influence health and nutrition behaviours. The relationship between poverty and self-regulation – risk-taking, self-agency, executive control and goal setting – may be mediated by changes in brain development influencing immediate and long-term health and well-being.

2.2 Social processes: role transitions and gender norms

Adolescents go through key role transitions in life. Starting in mid-adolescence, they begin to assume responsibility for their own health. In LMICs, most enter the formal or informal labour force and parenthood. Globally 11 per cent of 15- to 19-year-old girls give birth to children, 95 per cent of these in LMICs. Early pregnancy and child birth has profoundly adverse consequences for these girls as well as their children (Bundy et al., 2017; Kågesten et al., 2016)

Sex-differentials in morbidity and mortality between boys and girls are rooted in gender norms; it is in adolescence when expectations for boys and girls to follow norms sets in. Gender norms that

prescribe different status, power and opportunities to girls and boys according to culturally appropriate versions of masculinities and femininities can be harmful (Kågesten et al., 2016).

While the period of adolescence is characterized by substantial nutritional challenges, it can also provide a major window of opportunity for preparing for healthy productive and reproductive life and prevent the onset of nutrition-related chronic disease in adult life. Adolescence, a period characterized by openness to new ideas, provides an opportunity for adoption and consolidation of sound dietary habits (WHO, 2005).

Realizing the maximum potential for these complex and interlinked biological and social processes in youth can have a lasting impact on physical, cognitive, emotional, social and economic resources that are the foundation for current, future and intergenerational health and well-being. Rural transformations may positively influence these conditions by their influence of socio-economic status of the youth, their food environments, health infrastructure and other social processes such as gender norms that influence diet quality, nutritional status and economic outcomes.

3. Rural transformation and rural youth nutrition: a conceptual framework

Our conceptual framework relating the nutrition outcomes of rural youth to rural transformation processes draws on three interlinked frameworks: (1) the World Health Organization (WHO) framework on nutritional problems and causal factors in adolescence (WHO, 2005); (2) the Agriculture, Nutrition and Health (ANH) Academy Food Environment Working Group's framework on food environments and dietary outcomes (Turner et al., 2017); and (3) IFAD's conceptualisation of rural transformation processes and their role in transformation of agri-food systems in the context of globalisation (IFAD, 2016). We briefly describe these frameworks before setting out the framework used for this study

3.1 Determinants of malnutrition among adolescents: the WHO framework

While nutrition influences growth and development throughout infancy, childhood and adolescence, it is during adolescence that nutrient needs are the greatest (WHO, 2014). As described above, inadequate nutrition can lead to a range of physiological, anatomical and functional disturbances. The WHO's framework recognises the nutritional vulnerabilities of adolescents as well as the opportunities that adolescence provides for improving nutritional outcomes. The nutritional vulnerabilities may arise because of the high nutrient requirements for growth for adolescents, their dietary patterns and lifestyles, their risk-taking behaviours and their susceptibility to environmental influences.

The framework sees the double burden of malnutrition among adolescents as an outcome of overlapping determinants such as livelihoods, sub-optimal dietary intakes, early pregnancy and infections, and other health-related behaviours. The nutritional outcomes of these interactions may be mediated by undernutrition during early life. While the framework recognises the role of socio-economic factors and psychological factors in determining diets, its focus on the social processes, norms and living conditions (for example, intra-household allocation of nutrient-rich foods) that young people face is less well elaborated. The framework recognizes the role of food systems – food supply deficits, processed foods and access to safe and nutritious foods – in influencing diets.

3.2 Food environments: ANH Academy Food Environment Working Group framework

"Food environments" delineate the context – constraints and opportunities – within which consumer and household decision on food acquisition and consumption are made. The ANH Academy Food Environment Working Group (Turner et al., 2017) defines the food environment as "the interface that mediates one's food acquisition and consumption with the wider food system encompassing dimensions such as availability, accessibility, affordability, desirability, convenience, marketing and the properties of food sources and markets" (p.2).

The framework identifies two principal domains of the food environment – the external food environment and the personal food environment. The external food environment relates to the world of opportunities and constraints "out there" and includes exogenous dimensions such as food availability prices, vendor and product properties. The personal food environment includes a set of endogenous dimensions including food accessibility, affordability, convenience and desirability. The ANH Academy Food Environment Working Group proposes that the food environment acts as an important interface between the wider food system and people's food acquisition and consumption through continuous and complex interactions between the external and personal food environments.

The "food environment" is a useful construct for understanding how changes in national and global food production, storage, transportation and marketing systems are revealed in an individual's daily life and influence their dietary choices and patterns.

3.3 Rural transformation

Rural transformation refers to the process of economic and social and cultural change in rural areas in the context of the overall structural transformation of the economy associated with the process of economic growth and development. While there are several definitions of rural transformation in the literature, the definition provided by Berdegué et al. (2014) has been widely adopted:

> *"Rural transformation is a process of comprehensive societal change whereby rural societies diversify their economies and reduce their reliance on agriculture; become dependent on distant places to trade and to acquire goods, services, and ideas; move from dispersed villages to towns and small and medium cities; and become culturally more similar to large urban agglomerations. The rural transformation is the result, first of all, of the action of global drivers, such as the diversification of rural economies away from agriculture, the globalization of agri-food systems, and the urbanization of rural regions. While global forces drive this transformation, they are mediated by localized social structures, institutional frameworks, and local societies with different levels of human agency. The interplay of global and local factors explains why the rural transformation between and within different countries has different outcomes in terms of economic growth, social inclusion, and environmental sustainability." (Berdegué et al., 2014, chap.27 p.1)*

IFAD (2016) views rural transformation processes as being situated within the overall structural transformation of the economy and encompassing agricultural transformation and diversification of rural livelihoods. Structural change in the economy may be driven by a thrust towards industrialisation, globalisation through larger international trade flows and flows of capital, and macro policies affecting agricultural and food systems.

> *"Rural transformation (RT) involves rising agricultural productivity, increasing commercialization and marketable surpluses, and diversification of production patterns and livelihoods. It also*

> *involves expanded decent off-farm employment and entrepreneurial opportunities, better rural coverage and access to services and infrastructure, and greater access to, and capacity to influence, relevant policy processes. All of this leads to broad-based rural (and wider) growth, and to better managed, more sustainable rural landscapes". (IFAD, 2016, p.23)*

In this background paper, the effect of rural transformation processes on the nutrition and health of rural youth in developing countries is seen as being mediated by their impact on agri-food systems and the resultant "food environment" faced by rural youth that determines the food sources and types of products that they are exposed to in their daily lives.

3.4 Rural transformation and nutrition outcomes among youth: onceptual framework used for this paper

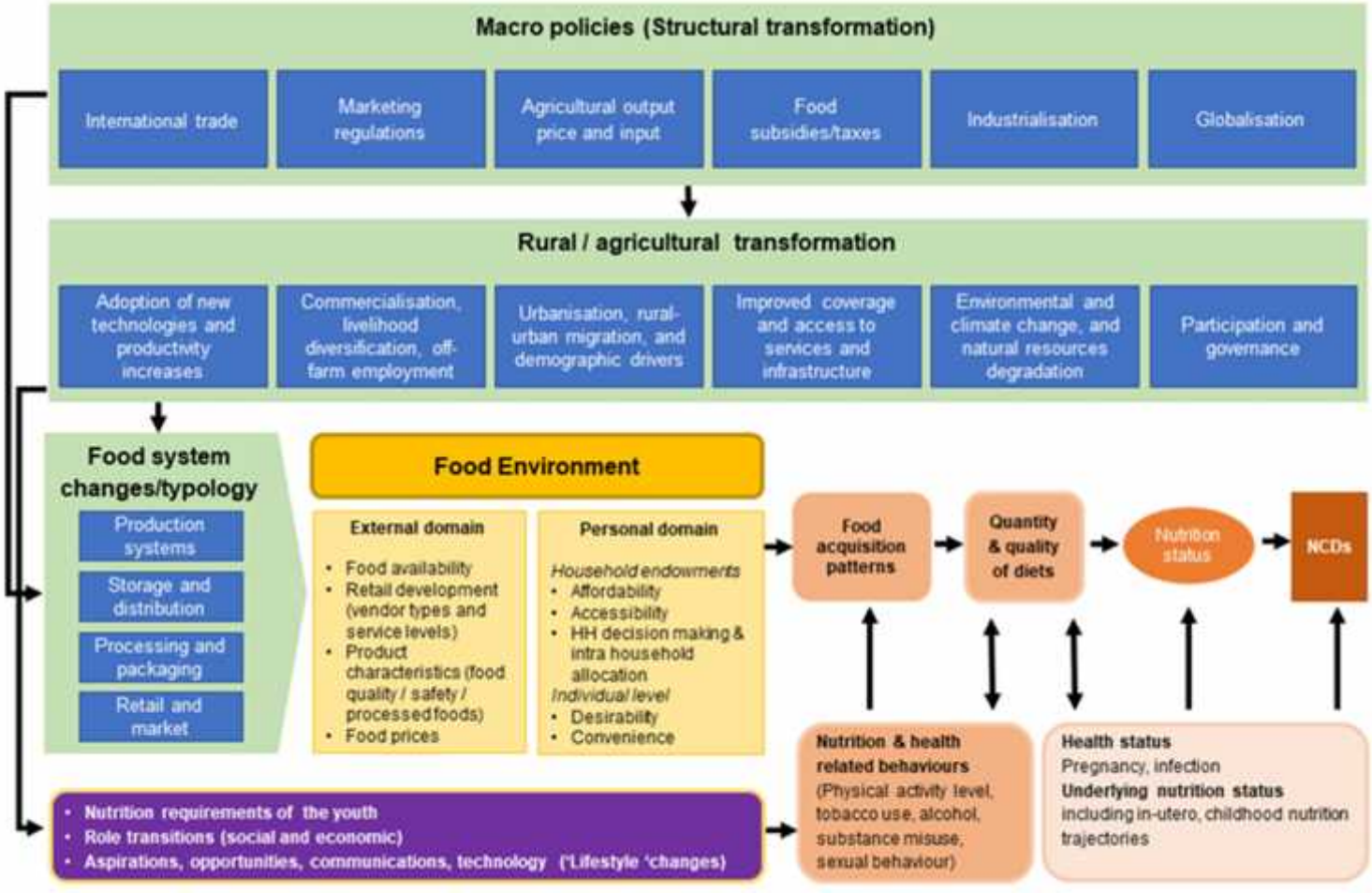
Figure 1 sets out the conceptual framework which links rural transformation processes to rural youth nutrition outcomes adopted in this paper.

The conceptual framework views rural transformation processes and socio-cultural norms as the principal drivers of the proximal determinants of rural youth nutrition and health which are (1) dietary intakes, (2) nutrition and health related behaviours and (3) childhood and pre-adolescence nutrition experience. The effects of these proximal determinants are influenced by the household and community living conditions (e.g. dwellings, access to sanitation and drinking water) of rural youth.

The principal determinants of dietary intakes of rural youth are the external and personal food environments that they face and the tastes and preferences of rural youth. Diets of rural youth may be influenced by their socio-economic status, nutrition requirements, role transitions (to employment or motherhood), prevalent social and cultural norms, opportunities and aspirations, and lifestyle preferences shaped by exposure to technology and media. These preferences are also conditioned by the attitudes of rural youth towards dietary and health behaviours.

Rural transformation processes play a major role in shaping agri-food systems covering production, storage and distribution, processing, marketing and retail (Timmer, 2014). The external and personal food environments faced by rural youth are derived from translation of the agri-food system to local geographies, which in turn affect dietary transformations, almost always following the robust laws of economics: Engle's law (declining share of food in the budget of all families as they become richer) and Bennet's law (the share of food budget on starchy staples decreases and share of non-staples increases).

Figure 1. Conceptual framework linking rural transformation and rural youth nutrition



Rural transformation processes also influence household and community living conditions. Increases in agricultural productivity and production have played a significant role in the reduction of rural poverty in LMICs (World Bank, 2008). Commercialisation of agriculture, production for the market and increased market participation of smallholders has wrought fundamental change in agri-food systems, with over 60 per cent of food even in rural areas being purchased or acquired from markets. Diversification of production patterns and livelihoods, off-farm employment and entrepreneurship, and rural-urban migration affect household incomes and wealth status. Improved rural coverage and access to services and improved transport and public health infrastructure influence household and community living conditions, disease prevention and the incidence of health hazards.

Rural transformation processes occur within the framework of macroeconomic policies related to international agricultural and food trade, agricultural price policies, agricultural input subsidies, food subsidies, public distribution systems in rural and urban areas, and foreign direct investment in the agri-food sector. Some of these macroeconomic policies may also have a direct impact on the food environment. Foreign direct investment in the food retail sector has led to the "supermarket revolution" that is making a major contribution to the nutrition transitions in LMICs (Reardon and Timmer, 2007). Socio-cultural norms are not static and are subject to change as a result of ongoing rural transformation processes.

The changes in the external and personal food environments brought out by food system changes, which in turn are affected by rural transformation processes (e.g. better access to safe and nutritious foods, improvements in household endowments) can facilitate consistent improvements in the nutritional status of rural youth (Jaacks et al., 2015). At the same time, other changes in the food environment (e.g. promotion of unhealthy "junk" foods, increased availability of processed foods) can promote unhealthy dietary behaviours. Youth are a key target for food marketing by multinational and domestic corporations. Key food marketing strategies include portfolios of foods such as "fun-for-you" (e.g. include chips, sugar-sweetened beverages), "good-for-you" (e.g. diet beverages, cereal bars) and "better-for-you" (e.g. breakfast cereals, packaged juices) (Elliott, 2015). Elliot argues that "gamification of food", i.e. making food fun, distances low-nutrient, highly processed foods from the negative health consequences of their consumption and is an increasingly important food marketing strategy employed to attract children and youth. Furthermore, in addition to mass media, young people are exposed to large numbers of advertisements for unhealthy foods and drinks on their way to and from school, and these are particularly clustered within the immediate vicinity of schools (Chacon et al., 2015; Kelly et al., 2015).

Thus, rural transformation processes are likely to be associated with both positive and negative aspects of rural youth nutrition transitions in LMICs.

4. Literature on trends in nutrition status of rural youth in LMICs

"Rural youth" as defined in this report (15-24 years) has not been used as a unit of analysis in the empirical assessments of trends in nutritional status in LMICs. Consequently, the literature examining trends in rural youth nutrition is rather sparse. Global assessments such as the United Nations Food and Agricultural Organisation (FAO) State of Food Security and Nutrition in the World and the multi-stakeholder Global Nutrition Report assess trends in nutritional status for children under five years and for adults (mostly adult women) but do not examine trends for rural youth. Other studies assess trends in the nutritional status for adolescents (WHO, 2005; Cappa et al., 2012) or other specific age groups within rural youth. These assessments are based on nationally representative surveys and datasets such as the Demographic and Health Surveys (DHS; www.dhsprogram.com) and other health and education surveys. Patton et al. (2012) have attempted a synthesis of internationally comparable data

on the health of the world's adolescents through a comprehensive review of available datasets, which also highlights the limited availability of data on the nutritional status of adolescents in LMICs. Nutritional status data in many nationally representative datasets is often confined to children or women in the reproductive age group and is generally not disaggregated by urban or rural locations. Assessing changes in the rural youth nutrition associated with rural transformation processes in LMICs is, therefore, subject to substantial data challenges.

An important contribution to the present knowledge of nutrition in adolescence has been made by the International Center for Research on Women/USAID Nutrition of Adolescent Girls Research Program, which was established in the 1990s to guide formulation of policies and programmes. The program included eleven research projects in Latin America, the Caribbean, Asia and Africa and included both cross-sectional and longitudinal studies (Kurz and Johnson-Welch, 1994). Stunting in adolescents was highly prevalent in nine of the 11 studies, ranging from 27 per cent in Guatemala to 65 per cent in the rural Philippines. The studies found adolescent boys to be generally worse off than girls except in India. Undernutrition, defined as BMI below the fifth percentile of National Center for Health Statistics/WHO reference values, [2] was highly prevalent in India (53 per cent), Nepal (36 per cent) and Benin (23 per cent). However, even where the prevalence of undernutrition was high, BMI tended to improve with age, which may reflect later maturation. In most of the studies comparing adolescent boys with girls, there was twice as much undernutrition in boys as in girls.

Using DHS datasets and nationally representative datasets from Indonesia, Viet Nam, China, Brazil and Mexico, Jaacks et al. (Jaacks et al., 2015) examined recent trends in underweight and overweight among adolescent girls in a set of 53 countries. The study found that underweight among adolescent girls remains a significant concern, with rural areas in two thirds of the countries having a higher prevalence of underweight compared to overweight. For rural areas, the highest prevalence of underweight was in South Asia (42 per cent) followed by East Asia and the Pacific (23 per cent) and sub-Saharan Africa (19 per cent). Latin America and the Caribbean (12 per cent), Eastern Europe and Central Asia (11 per cent) and North Africa (4 per cent) had much lower rates of underweight prevalence. The high prevalence of underweight in South Asia reflects the high prevalence of underweight in India (>40 per cent), while Bangladesh and Nepal also have a prevalence rate greater than 20 per cent. All East Asian and Pacific Countries, including China, had an underweight prevalence rate greater than 20 per cent. Sub-Saharan Africa shows considerable variation in the prevalence of underweight (ranging from 36 per cent in Senegal to 10 per cent in Sierra Leone), while the prevalence of underweight is quite low in Latin America and the Caribbean, with only three countries (Brazil, Guyana and Haiti) having a prevalence rate greater than 10 per cent. The high prevalence of underweight among adolescents in South Asia, which is more than twice that in other regions, has been noted in a number of studies, including a systematic review of underweight in adolescents in seven Asia countries by Mak and Tan (2012) and others (Aguayo and Paintal, 2017; Ahmed et al., 1998; Chaturvedi et al., 1996; Kurz and Johnson-Welch, 1994; Venkaiah et al., 2002; WHO, 2006).

Jaacks et al. (2015) find that prevalence of underweight among adolescent girls is decreasing in all regions with the exception of South Asia and Eastern Europe and Central Asia. The largest decreases in underweight prevalence are seen in sub-Saharan Africa (rural Zambia, urban Nigeria and urban Mali) and Asia (urban Bangladesh and urban China), while the largest increases are also occurring in sub-Saharan Africa (rural Senegal and urban Niger) and Asia (rural Bangladesh and urban Nepal). In several countries, the direction of change in the prevalence of underweight among adolescent girls is different between rural and urban areas.

[2] www.motherchildnutrition.org/malnutrition-management/info/nchs-who-normalized-reference.html

Studies examining the prevalence of overweight and obesity appear to suggest that increasing prevalence is a feature of all regions and countries. Reviews of worldwide trends in childhood overweight and obesity (Poskitt, 2009; Wang and Lobstein, 2006) indicate that no LMICs have avoided the phenomenon of increasing overweight and obesity among children. Studies from India (Midha et al., 2012), China (Gordon-Larsen et al., 2014) and Mexico (de Onis et al., 2007) all suggest a significant increase in the incidence of obesity and overweight for children and adolescents. For rural areas, Jaacks et al. (2015) report the highest prevalence of overweight for adolescent girls in North Africa (41 per cent) followed by Latin America and the Caribbean (21 per cent). The prevalence of overweight in adolescent girls is much lower in sub-Saharan Africa (7 per cent), East Asia and the Pacific (8 per cent) and Eastern Europe and Central Asia (8 per cent) with South Asia having the lowest prevalence (1 per cent). The study notes that the prevalence of overweight is increasing in all regions except Eastern Europe and Central Asia and South Asia. The highest prevalence of overweight in rural areas was found in Egypt and in Latin American countries (Mexico, Bolivia and Nicaragua). In the sample of 53 countries analysed by Jaacks et al. (2015), underweight in rural areas is increasing in 16 countries while overweight is increasing in all but eight countries. Therefore, it appears that the majority of LMICs undergoing rural transformation are likely to be confronted with the double burden of malnutrition, which may increase over time for some countries. Jaacks et al. (2015) suggest that somewhere around a GDP per capital level of US$2,500, the burden of overweight/obesity in LMICs begins to shift from the affluent to the poorer segments of society.

5. Methodology

The empirical analysis follows a two-step approach. We will first describe global trends in the double burden of malnutrition vis-à-vis structural and rural transformation and food environment proxies across time and space in LMICs. Later, we will dive into four country case studies. The next sub-sections present methodological details.

5.1 Global trends

We merged different sources of data to investigate the global and regional trends of nutritional status of adolescents/rural youth with indicators capturing rural transformation and diets. We examine trends in nutritional status indicators and associate them with trends in rural transformation variables. The key dependent nutrition status variables are mean BMI; thinness; and overweight and obesity. For young people up to 12-19 years, BMI is measured through BMI-for-age z-scores (BAZ) (de Onis et al., 2007). Z-scores were constructed as deviation of the individual-level observation from the median of the reference standard by age and sex. A dichotomous variable that assumed the value of 1 if the adolescent was too thin for her age was constructed if BAZ was below -2SD from the reference standard. Similarly, a dichotomous variable for overweight and obesity was constructed for those adolescents with BAZ above 1SD from the reference. In the case of adolescents aged 19-24 years, BMI was measured as the ratio of weight in kilograms over squared height in metres. For this age group, the threshold for defining thinness was defined as a BMI below 18.5 kg/m2, and for overweight and obesity above 25 kg/m2. We describe the trends in these indicators from 1976 to 2016 by age groups and by gender using data from the NCD Risk Factor Collaboration (NCD-RisC, 2017; see this source for details on the methodology used to construct the dataset).

We examined long-term trends in adolescent nutritional status alongside variables capturing rural transformation and diet. Agriculture value added per worker (constant 2010 US$) was used to capture rural transformation. Two dimensions of rural transformation, level (high/low) and speed (fast/slow), were computed in order to define countries in four categories. The level of rural transformation is defined as whether a country was below or above the global median agricultural value added per

worker. The speed of rural transformation was calculated as the average annual change of agricultural value added per worker (1990-2016). Supplementary Table 1 reports the full sample of countries (n=78) used in the analysis and their typology of rural transformation in four categories (high/fast; high /slow; low /fast; low/slow). A separate category of "resource-rich countries" (15 countries) was used in the analysis, as the rural transformation patterns of these countries appeared to be distinct from those of other countries.

We used FAO's FAOSTAT data to provide proxy measures of food systems and structural shifts in dietary patterns at the population level. Specifically, we rely on data capturing food supply (kilocalories per capita per day), fat supply quantity (grams per capita per day), fruit and vegetable consumption (grams per capita per day), and sugar intake (kilocalories per capita per day). Due to the lack of comparable data across countries and years, the timeframe for analyses using FAOSTAT data is 1976-2012.

The global databases that we have used to provide trends are not without limitations. First, data on dietary supply does not provide age disaggregated data, and therefore we have to assume that the diet of the population is representative of that of rural youth. The anthropometry data (BMI, thinness, overweight and obesity) were available disaggregated by age groups and gender. Secondly, neither data on anthropometrics from NCD-RisC nor FAO's data on diets are granular enough to provide a breakdown by area of residence. Nonetheless, these trends show how rural transformations can affect nutritional status of youth in general. We focus on rural youth through use of the Young Lives panel data (see below). Finally, in the estimations the countries are not population-weighted.

5.2 Country case studies from Ethiopia, India, Peru and Viet Nam

Data

Data for the country case studies were drawn from Young Lives, a longitudinal study of childhood poverty conducted in Ethiopia, India (in the states of Andhra Pradesh and Telangana), Peru and Viet Nam (Barnett et al., 2013). The study followed a sample of 12,000 children for 15 years. The sample in each country consisted of two cohorts of children: a younger cohort (n=2,000 per country) which was aged between 6 and 18 months at the study inception in 2002, and an older cohort (n=1,000 per country) which was aged between 7.5 and 8.5 years. Data were subsequently collected in 2006, 2009, 2013 and 2016, when the younger cohort was aged, respectively, 5, 8, 12 and 15 years, and the older cohort was aged 12, 15, 19 and 22 years. For this study, we use data for the younger cohort at 12 years and for the older cohort at 12, 15 and 19 years. Unfortunately, data from the 2016 round were not yet available for public use at the time of the draft of this report; therefore, we could not include them in our analysis.

Within each country, children and their families were randomly selected from 20 sentinel sites, which, hereafter, we will refer to as "communities". This sampling strategy comes from health surveillance studies and is a form of purposive sampling where the community was chosen to represent the geographical, economic, social and ethnic variation of population living in the specific area. Also, the poorest families were oversampled within each community. For these reasons, the sample is not nationally representative (or, in the case of India, state-representative). However, comparison of key child outcomes or socio-economic variables show that the variation found in Young Lives communities is very similar to the patterns found in nationally representative surveys, which makes the survey an appropriate and valuable tool to analysing child well-being and its dynamics (Barnett et al., 2013). Attrition is exceptionally low, as compared to similar longitudinal studies.

Nutritional outcomes

Mean BMI, thinness and overweight and obesity were used as main study outcomes in the case studies (described in Section 4.1). Further, we constructed the following indicators of youth dietary quality: individual dietary diversity and consumption of specific food groups (e.g. sugars, animal source foods, fruits). Individual dietary diversity is considered as a good proxy for nutritional adequacy of the diet (Coates et al., 2007; Ruel, 2003). This indicator was measured as the sum of the following food groups consumed by the adolescent in the previous 24 hours from a predefined list of foods, which was adapted to suit each country's context: (1) grains, roots and tubers; (2) fruits and vegetables; (3) meat, offal and fish (generically called "meat and fish"); (4) eggs; (5) pulses, legumes and nuts; (6) milk and milk products; and (7) food cooked in oil or fat. Therefore, the index ranges from 0 to 7. Foods with added sugars were not included in the dietary diversity measure as they do not contribute to healthy diets.

Three binary indicators of consumption of critical food groups were also constructed: (1) consumption of animal source foods, which assumed the value of one if the adolescent consumed any meat, milk and dairy, fish or eggs in the previous day; (2) consumption of fruits; and (3) consumption of added sugars. The first two indicators were included due to the relevance of both animal source foods and fruits to nutritional outcomes. Animal source foods are important sources of protein and micronutrients, which are particularly important in a stage characterised by rapid growth and susceptibility to infection such as adolescence and young adulthood. Similarly, fruits are a key dietary source of vitamins and minerals. On the other hand, rapid global increases in consumption of added sugars is related to the rapid nutrition and epidemiological transition towards overweight and diet-related disease such as Type 2 diabetes (Popkin and Gordon-Larsen, 2004).

Indicators of rural transformation and food environments

Although Young Lives includes a wealth of information on adolescents' households and communities, the task of identifying suitable indicators of rural transformation and food environments for this analysis was far from being a simple one. On the one hand, we attempted to include indicators that would be consistent with the conceptual framework on rural transformation and food environments outlined in Section 2; on the other hand, we faced substantial challenges in identifying indicators that were collected in a coherent fashion both over time and across countries. Indeed, although the dataset is rather standardised across countries, there are still inevitable context specificities in the way data were collected within each single country. This context specificity was particularly salient with regards to the community data. In turn, this prevented us from using those for identifying potential indicators related to community characteristics such as distance from markets, availability of markets and other potential proxies for rural transformation that were collected in the same way across countries and over time.

Therefore, we relied exclusively on the household survey data. Based on availability and consistency in data collection across countries and over time, we selected mean access to services at the community level and mean share of bought food over total food consumption at the community level as key indicators of rural transformation and food environments respectively. [3]

Average access to services at the community level was constructed in a two-step process. First, for each survey round and country household access to services was measured as a composite indicator, aggregating through a simple average four binary indicators related to whether the household had access to drinking water, sanitation, electricity and adequate fuels for cooking (Azubuike and Briones,

[3] We also explored the use of mean share of food expenditure over total consumption expenditure in the community as a proxy of overall poverty in the community, and employment in off-farm rural activities at the community level as a proxy for rural shifts in labour market participation from agricultural to non-agricultural labour. However, the former indicator did not yield enough variation over time to be included in the analysis, while the latter was not consistently captured in all survey rounds and countries.

2016). In turn, data were aggregated among all households belonging to the same rural community in each country and survey round, independently of whether the adolescent belonged to one cohort or the other.

Mean access to services at the community level was chosen to represent rural transformation because we expect access to services to changes as rural economies change (Dornan and Ogando Portela, 2014). We hypothesise that improvement in access to services improves BMI, reduces the probability of thinness among adolescents, and has a variable impact on overweight and obesity based on the baseline nutritional status of adolescents in these communities. Changes in specific food group consumption will depend on baseline consumption patterns of these food groups and substitution effects, which in turn determines the dietary diversity score.

The proxy indicator of food environments was measured through the share of bought food over total food consumption at the community level. We expect that as rural economies undergo transformations, where and how people acquire food changes, and we expect an increase in bought food as rural economies move out of subsistence agriculture. We expect this variable to be an interaction of personal (affordability and physical access to these markets) and external food environment (presence of functioning markets and prices and availability of food products). We hypothesize that as rural economies diversify, and their economic well-being improves, individual dietary diversity improves due to changes in food environments and changes in preferences (Bennet's law), especially in communities with low baseline development. We expect this indicator to increase BMI of adolescents, lower the probability of thinness, and have a variable impact on overweight and obesity based on the baseline nutritional status of adolescents in these communities and the food purchase choices made within a given food environment. We expect changes in types of food products consumed, but overall dietary diversity score will depend on the substitution effects. The indicator was measured first by calculating share of bought foods over total food consumption in the household-level data for each survey round and country (see Azubuike and Briones, 2016 for further detail on how consumption expenditure was measured in each country and round). As for services, we then aggregated household-level information at the community level for each country and round.

Finally, both indicators were standardised to have a mean of 0 and SD of 1 in order to be comparable between each other, over time and across countries.

Statistical analysis

The country case study analysis starts off by describing trends in select nutritional outcomes, by focusing on urban-rural differences in thinness and overweight and obesity, and generational shifts in dietary patterns between the younger and the older cohort when they were both aged 12 years.

We conducted multivariate analyses to assess associations between proxies of rural transformation and food environments on adolescent nutritional outcomes. Controlling for a set of child and household characteristics, data from both cohorts at different ages were pooled together and treated as a repeated cross-section through the following specification:

$$y_{ij.t} = \beta_0 + \beta_1 RT_{j.t} + \beta_2 FE_{j.t} + \beta_3 X_{ij.t} + \beta_4 Cohort_{ij} + \beta_5 AgeGroup_{ij.t} + \varepsilon_{ij.t} \quad (1)$$

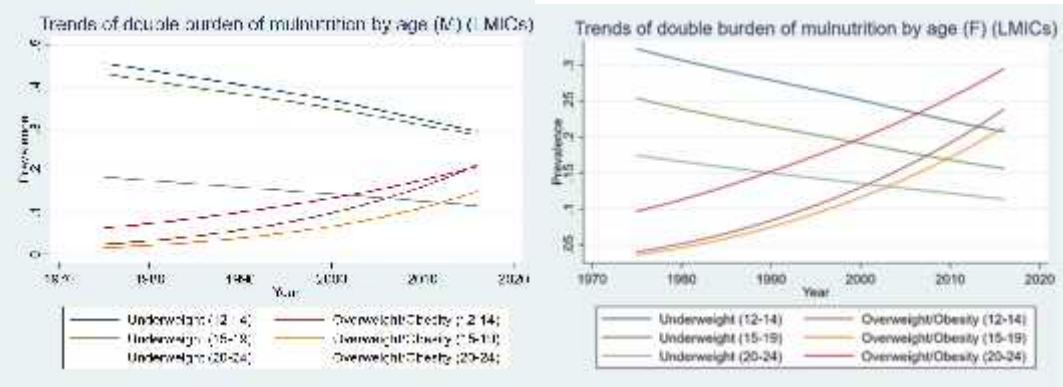
Where $y_{ij.t}$ relates to nutritional outcome of adolescent i, living in community *j* and measured at time *t*; $RT_{j.t}$ relates to rural transformation; $\beta_2 FE_{j.t}$ is the food environment variable; and $X_{ij.t}$ relates to contemporaneous observable child, parental and household characteristics. $\varepsilon_{ij.t}$ is the error term. Rural transformation and food environment indicators were measured by the indicators mentioned in the previous section. The vector of child and household covariates $X_{ij.t}$ includes the following: adolescent's age in months; sex; maternal years of schooling; household size; and household wealth.

In order to estimate age- and cohort-specific associations, age- and cohort-specific dummies were included, as dietary or other nutritional outcomes can vary by both age and cohort (Aurino et al., 2017). All models were estimated through ordinary least square (OLS) and linear probability model (LPM) regressions with standard errors clustered at the community level. Note that all models were only estimated on the rural sample of the Young Lives study. The present empirical strategy only aims at documenting patterns of associations between rural transformation and nutrition of youth and does not claim any causality.

6. Global trends in rural transformation and the double burden of malnutrition among youth

Figures 2a and 2b present trends in thinness (shown as underweight in NCD-RisC data) and overweight/obesity by different age groups – early adolescents (12-14 years), mid-adolescents (15-19 years) and youth (20-24 years) – over the period 1976-2016 for LMICs included in the sample. The prevalence of thinness has shown a large decline over this 40-year period for both boys and girls. However, thinness, reflecting undernutrition, remains substantial in the younger (12-14 years and 15-19 years) age groups. The incidence of thinness has fallen to less than 11 per cent over this period in the age group of 20-24 years. Prevalence of thinness is greater among boys than girls in the early-and mid-adolescence age groups. The large gap in thinness for males aged 20-24 years compared to the younger age groups perhaps represents the better opportunities that males have for catch-up growth in relation to females. The prevalence of overweight has shown a steady increase over time and is higher for females among all age groups. The highest increase in the prevalence of overweight/obesity is in the 12-14 years age group, where the increase in prevalence is similar for both boys and girls.

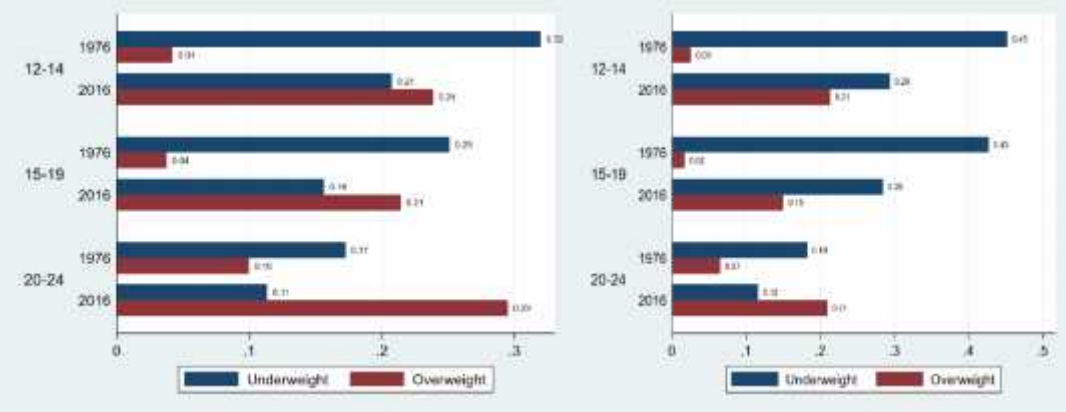
Figure 2a. Trends in underweight and overweight/obesity by age group and gender in LMICs (1976 2016)



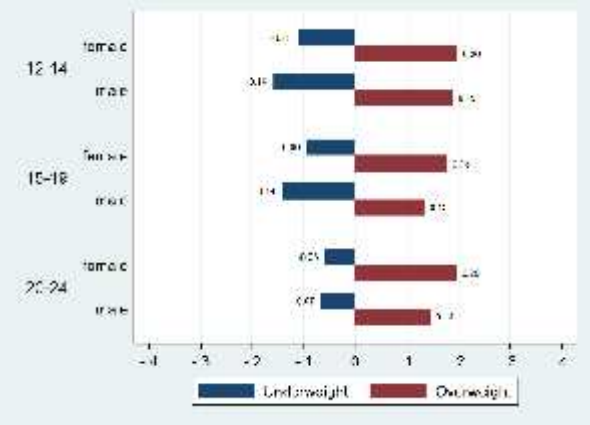
Source: Authors' calculations based on NCD-RisC data

Figure 2b. Levels (A) and percentage point changes (B) of underweight and overweight by age and sex groups in LMICs (1976 2016)

A (females – left; males – right)



B

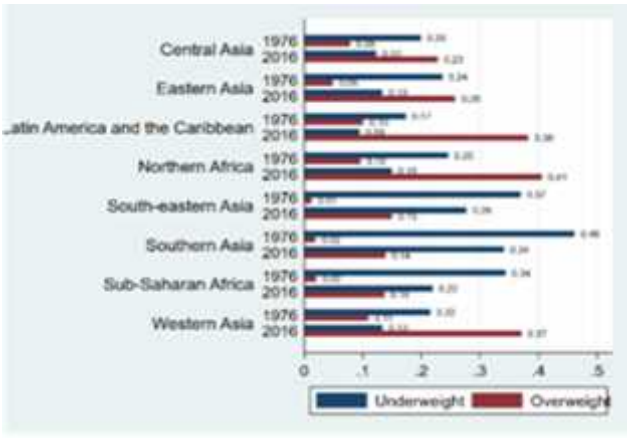


Source: Authors' calculations based on NCD-RisC data

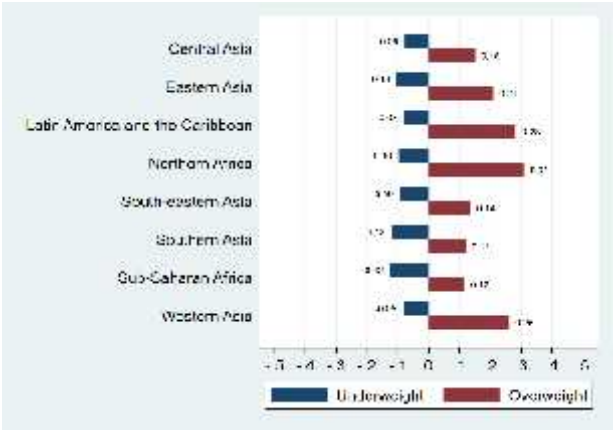
Figure 3 shows changes in the prevalence of thinness and overweight/obesity by geographic regions between 1976-2016 for the same set of LMICs. In most countries the reduction in the incidence of thinness (underweight) occurred simultaneously with an increase in the prevalence of overweight. While the incidence of underweight has fallen in all regions, it remains stubbornly high in South Eastern Asia and Southern Asia, with more than a third of the population remaining underweight. After the Pacific areas, Northern Africa and Latin America were characterised by the largest increases (>28 percentage points) in prevalence of overweight between 1976 and 2016. The larger increases in the overweight incidence compared with the reduction in underweight incidence in these regions has meant the proportion of the population with "normal" weight has declined over this time period. In South Eastern Asia, Southern Asia and sub-Saharan Africa, the offsetting changes in the incidence of underweight and overweight have left the proportion of the population with "normal" weight relatively stable.

Figure 3. Levels (A) and percentage point changes (B) of underweight and overweight prevalence for youth (12 24 years) by geographical region (1976 2016)

A



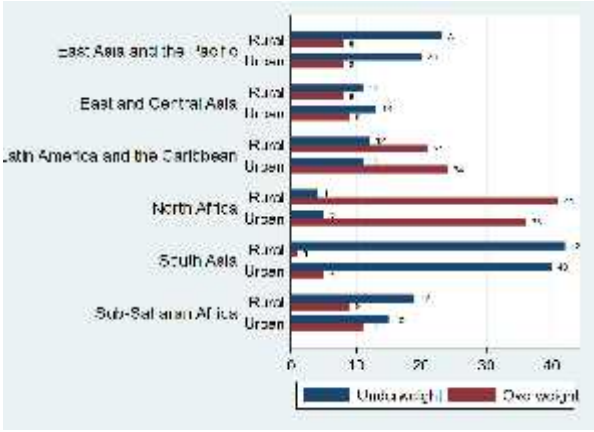
B



Source: Authors' calculations based on NCD-RisC data

NCD-RisC data, as noted above, does not provide disaggregation by area of residence. Jaacks et al. (2015) have examined the trends in the prevalence of underweight and overweight/obesity among 15-to 18-year-old non-pregnant adolescent girls using DHS data covering the period 1998-2010 (figure 4). Of the 53 countries included in their analysis, Jaacks et al. show that the prevalence of underweight in rural areas is decreasing in about 25 countries while the prevalence of rural overweight is increasing in all countries except Zambia and Zimbabwe. In urban areas, the authors report an increase in prevalence of both under- and overweight in 18 per cent of countries (about 10 of the 53).

Figure 4. Underweight and overweight prevalence among non-pregnant 15- to 18-year-old girls using the latest DHS data



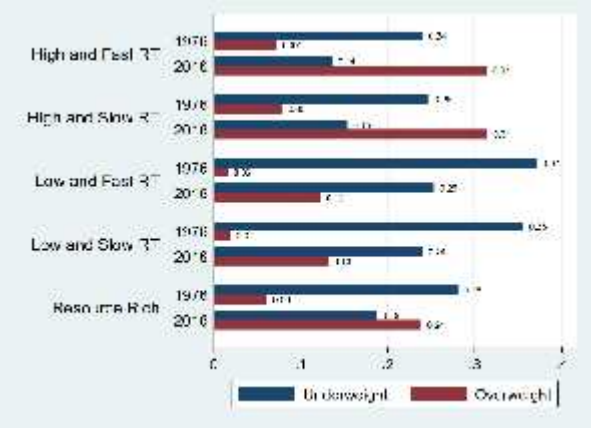
Source: Recreated from Jaacks et al. (2015)

Following the conceptual framework, we present changes in youth nutritional status indicators and food system change indicators (changes in food supply) by rural transformation typologies. The changes in youth nutritional status (1976-2016) by the level and speed of rural transformation are presented in figure 5 for the LMICs included in the analysis. The changes in the nutritional status of rural youth appear to be related more to the level of rural transformation at the start of the time period rather than to the speed of transformation. Countries with a high level of rural transformation (with a slow or fast pace of transformation) witness a 24 percentage point increase in the incidence of overweight/obesity alongside an 11 percentage point decrease in the incidence of underweight. Countries with a low level of rural transformation (with a slow or fast pace of transformation) witness a 12 percentage point decrease in the incidence of underweight and nearly the same percentage point increase in the incidence of overweight. Resource-rich countries have a similar percentage point decrease in the incidence of underweight but an 18 percentage point increase in the incidence of overweight. Thus, countries starting at a higher level of rural transformation and resource-rich countries appear to be prone to more rapid increase in the incidence of overweight/obesity.

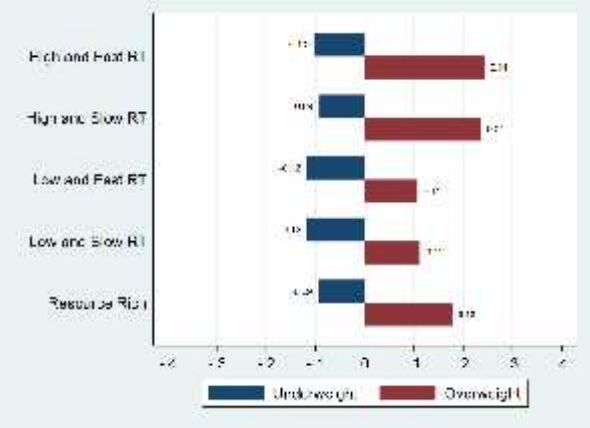
A breakdown by age groups provides additional granularity to the associations between the level and speed of rural transformation and nutritional status of youth (figure 6) in the LMICs included in the analysis. The largest increases in the incidence of overweight are seen among the early adolescents across the different typologies of rural transformation. Overall, the increase was higher in countries with high levels of rural transformation and in resource-rich countries. The percentage point reduction in the incidence of underweight is quite similar for all age groups across the rural transformation typologies. The reduction of underweight among early and mid-adolescents (12-14 and 15-19 years) in countries experiencing low and slow rural transformation was also associated with small increases in adolescents with normal weight.

Figure 5. Levels (A) and percentage point changes (B) of underweight and overweight prevalence by level and speed of rural transformation (RT) (1976-2016)

A

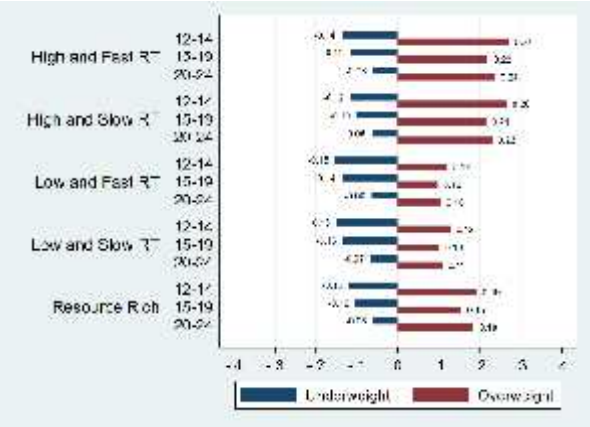


B



Source: Authors' calculations based on NCD-RisC data

Figure 6. Percentage point changes in underweight and overweight prevalence by level and speed of rural transformation (RT) and age group (1975 2016)

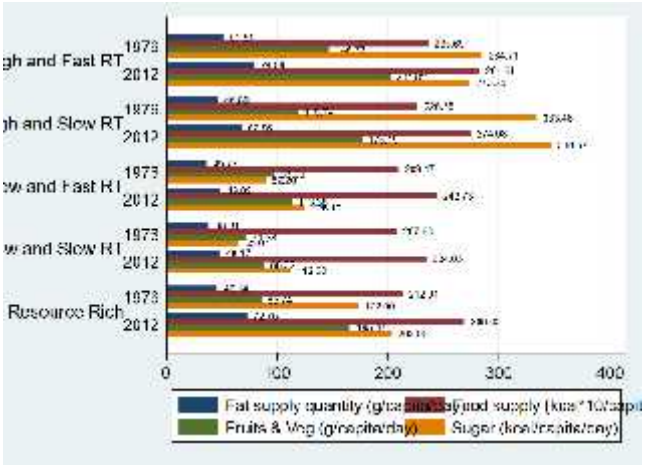


Source: Authors' calculations based on NCD-RisC data54

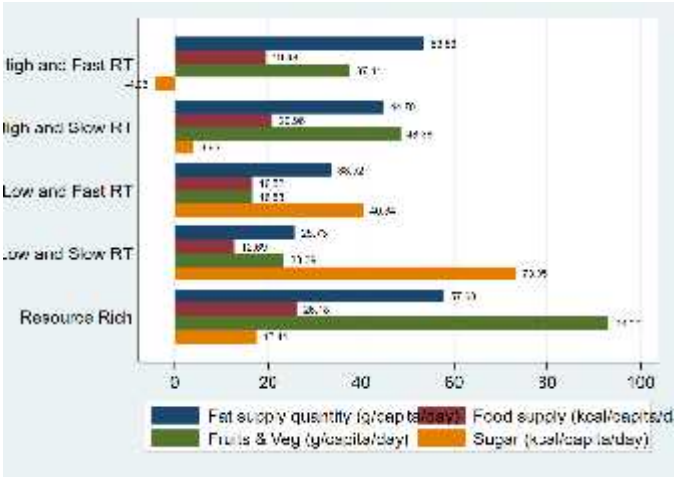
Figure 7 shows the changes in dietary supply indicators – calories, fats, sugars, and fruits and vegetables – across rural transformation typologies. While variation in calorie and fat consumption is limited across the rural transformation typologies, countries with high levels of rural transformation and resource-rich countries have significantly higher levels of sugar consumption and fruit and vegetable consumption than countries at low levels of rural transformation. What is striking is the very large percentage point increase in sugar consumption in low-rural-transformation countries (although they are starting from a lower base) even as the increase in sugar consumption in high-rural-transformation countries appears to be reaching a plateau.

Figure 7. Levels (A) and percentage point changes (B) of supply of fat, food, fruits and vegetables, and sugar by level and speed of rural transformation (1976-2012)

A



B

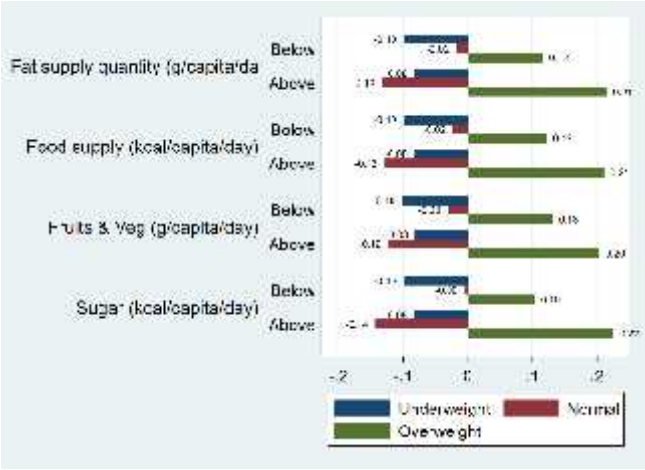


Source: Authors' calculations based on FAOSTAT and IFAD data

Figure 8 below shows how changes in the nutritional status of rural youth correlate with the levels of dietary supply indicators. For each dietary supply indicator, we examine changes in the incidence of underweight and overweight/obesity for countries having a value below or above the median value for the indicator. Values of dietary supply indicators below or above the median value do not appear to make a large difference to the reduction in the incidence of underweight. But they do make a large difference to the increase in the incidence of overweight. In countries with above-median values of the

dietary supply indicators, the increase in the incidence of overweight reflects a large reduction in the proportion of the population with normal weight; i.e., higher levels of dietary supply indicators push more of the "normal" population towards overweight/obesity.

Figure 8. Percentage point change in underweight, overweight and normal weight prevalence among youth by supply of fat, food, fruits and vegetables, and sugar (1976 2012)



Source: Authors' calculations based on NCD-RisC and IFAD data

7. Findings from the Young Lives countries

7.1 Study settings: the macro view

This section describes trends in select youth nutritional outcomes by relying on the Young Lives data from Ethiopia, India, Peru and Viet Nam. Before presenting empirical findings, we describe briefly the study settings. The four study countries vary greatly in terms of socio-economic development, urbanisation and stages in the nutrition transition (Aurino et al., 2017). Ethiopia had the lowest per-capita income and experienced the highest rate of economic growth over the study period among the four countries (Table 1). The other countries also underwent significant economic and social development.

Among the four countries, all except Ethiopia are characterised by high levels of structural transformation. However, Ethiopia, India and Viet Nam are characterised by low levels of rural transformation, while Peru is characterised by high levels of rural transformation.

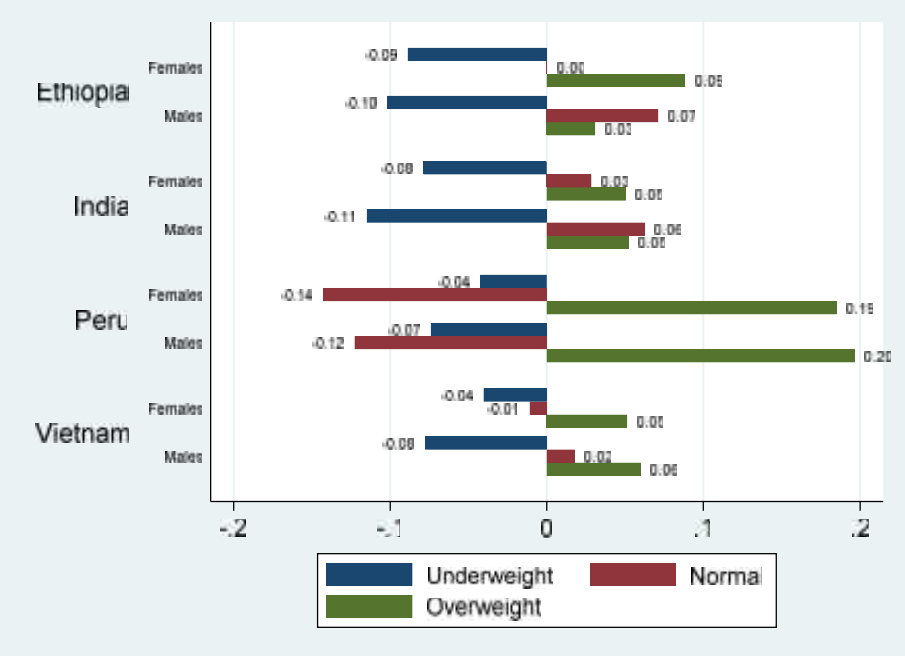
Table 1. Young Lives study settings: National level

	Ethiopia	India	Peru	Viet Nam
GDP per capita, 2016, constant 2010 international US$	511.2	1,861.5	6,089.4	1,735.3
GDP per capita growth, 2006-2013, annual %	7.7	6.1	5.4	4.9
Employment in agriculture, 2017, % of total employment	68	43	28	41
Share of rural youth in total population, %	16.7	11.7	3.9	11.1
Share of rural youth in total rural population, %	20.7	17.4	18.2	16.7
Level of structural transformation	Low	High	High	High
Level of rural transformation	Low	Low	High	Low

Source: Data on GDP, GDP growth and employment in agriculture retrieved from the World Bank World Development Indicators on 28 May 2018; structural and rural transformation data provided by IFAD

The long-term trends in the double burden of malnutrition in youth for those selected countries are shown in figure 9. Overall, the figure shows national changes in youth nutritional indicators that are broadly similar to the global ones, with a steady decline in underweight over time, and a steep increase in the burden of overnutrition, particularly in Peru, where overweight prevalence increased by 20 percentage points. In Viet Nam, the reduction in the incidence of underweight has been accompanied by an almost equal percentage point increase in the incidence of overweight, leaving the proportion of the population with a normal BMI relatively stable. This is observed in Ethiopia also among females. In India, the reduction in the prevalence of underweight has led to an increase in the proportion of the population with normal BMI.

Figure 9. Percentage point change in underweight, overweight and normal weight prevalence for youth in Ethiopia, India, Peru and Viet Nam (1975 2016)



Source: Authors' calculations based on NCD-RisC data

7.2 Descriptive findings on youth nutritional status

Table 2 presents descriptive statistics of nutritional status of the pooled Young Lives rural youth sample. Country-disaggregated statistics are presented in Supplementary Table 2. Overall, the double burden of malnutrition was present in the sample, with about 30 per cent (depending on age and cohort) of adolescents that were stunted, about 25 per cent of adolescents that were thin, and about 3 per cent that were overweight or obese. Also, the average adolescent had quite a monotonous diet, with a consumption of about four food groups in the previous day. Only about two thirds and one third of rural adolescents had consumed, respectively, animal source foods and fruits in the 24 hours before the survey. If we focus on the older (2006) cohort only, on which we have data at different stages of adolescence, it is remarkable how consumption of fruits was quite stable over time. On the other hand, there was a marked increase in the proportion of young people consuming added sugars between 12 years and later adolescence, moving, on average, from 50 per cent to 64 per cent of adolescents having consumed added sugars in the previous day. Wide differences were present across countries, as shown in Supplementary Table 3. This variation in consumption across countries and regions is also documented in a recent review of dietary patterns of 15- to 19-year-old girls using DHS data (Keats et al., 2018).

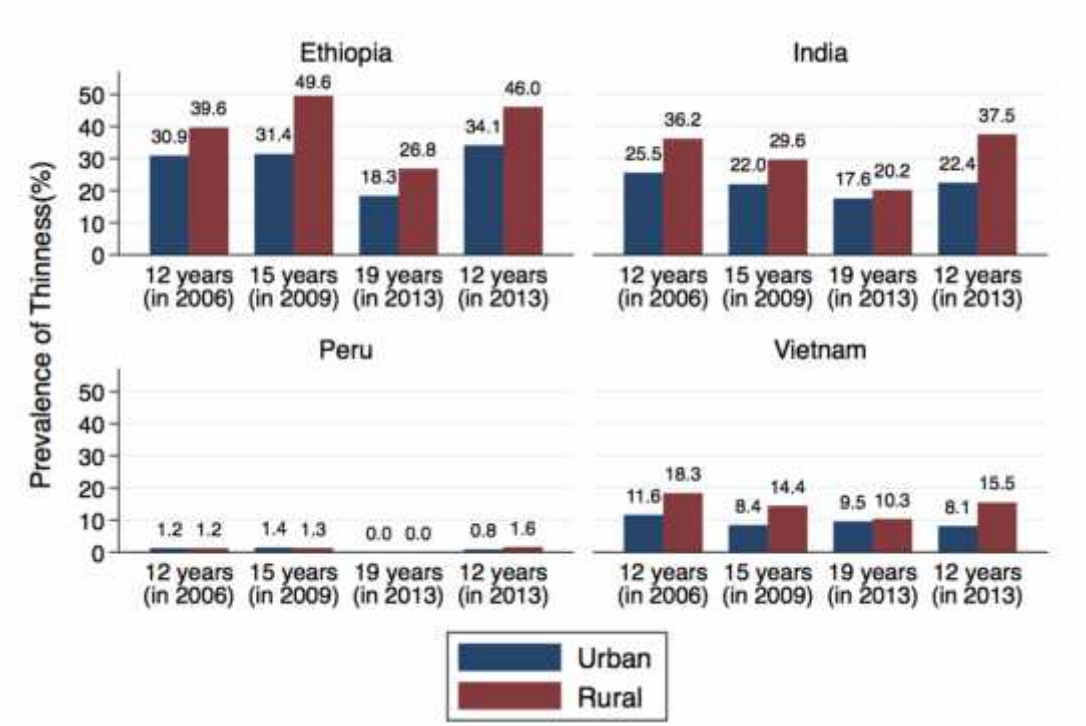
Table 2. Descriptive statistics of rural youth by age and cohort (Young Lives data)

	Older cohort (born 1994-95)			**Younger cohort (born 2001-02)**
	12 years (in 2006)	**15 years (in 2009)**	**19 years (in 2013)**	**12 years (in 2013)**
HAZ	-1.635 (1.088)	-1.615 (1.066)	-1.397 (1.015)	-1.477 (1.029)
BAZ	-1.364 (1.159)	-1.265 (1.210)	-0.973 (1.114)	-1.233 (1.294)
Stunted, %	37.3 (0.484)	34.0 (0.474)	27.4 (0.446)	30.1 (0.459)
Thin, %	28.5 (0.452)	27.5 (0.447)	18.1 (0.385)	28.2 (0.450)
Overweight or obese, %	2.27 (0.149)	2.12 (0.144)	3.40 (0.181)	4.59 (0.209)
Dietary diversity score	4.133 (1.137)	4.329 (1.072)	4.157 (1.060)	4.220 (1.128)
Ate animal source foods in the last 24 hou	69.5 (0.461)	77.5 (0.417)	72.9 (0.445)	78. (0.415)
Ate fruits in the last 24 hours, %	39.2 (0.488)	39.4 (0.489)	39.5 (0.489)	48.8 (0.500)
Ate added sugars in the last 24 hours, %	51 (0.500)	63.6 (0.481)	64.9 (0.478)	63.9 (0.480)

Notes: Mean with SD in parentheses. This table presents select nutritional outcomes for rural adolescents from the two cohorts of the Young Lives sample from Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam. BMI-for-age z-scores (BAZ) is an indicator of contemporaneous nutritional status, while height-for-age z-scores (HAZ) measures the history of health inputs. Both were calculated on the basis of the WHO International Reference Standards (de Onis et al., 2007). Starting from those, three dichotomous variables were generated: thinness, which assumes the value of 1 if BAZ < -2SD from the international reference standard; overweight and obesity, if BAZ > 1SD; and stunting, if HAZ < 2SD. Individual dietary diversity is a measure of an adolescent dietary variety and proxy for nutritional adequacy. Three dichotomous variables of whether the adolescent has eaten any animal source foods (meat, milk and dairy, fish and eggs), fruits and added sugars in the previous day were also generated**.**

Figure 10 presents prevalence of thinness at different ages and by urban and rural communities in the Young Lives study samples. Thinness in Ethiopia and India remain high, followed by Viet Nam. Urban-rural differentials ranging between 7 and 18 percentage points persist, with the burden being higher in rural than in urban areas. However, prevalence of thinness in urban areas is non-trivial, especially in Ethiopia and India. The comparison between the two cohorts at 12 years (i.e. the first two bars compared with the last two bars in each country chart) show that very little change in the prevalence of thinness occurred. Indeed, in Ethiopia, the prevalence of thinness increased slightly for the younger cohort (12-year cohort in 2013). The changes in prevalence of thinness among Indian children aged 12 years in 2006 and 2013 is not appreciable either. With the exception of Peru, boys were more likely to be thin than girls (overall prevalence of thinness: boys, 32 per cent; girls, 22 per cent; $p<0.001$).

Figure 10. Prevalence of thinness by place of residence, age and cohort (Young Lives data)

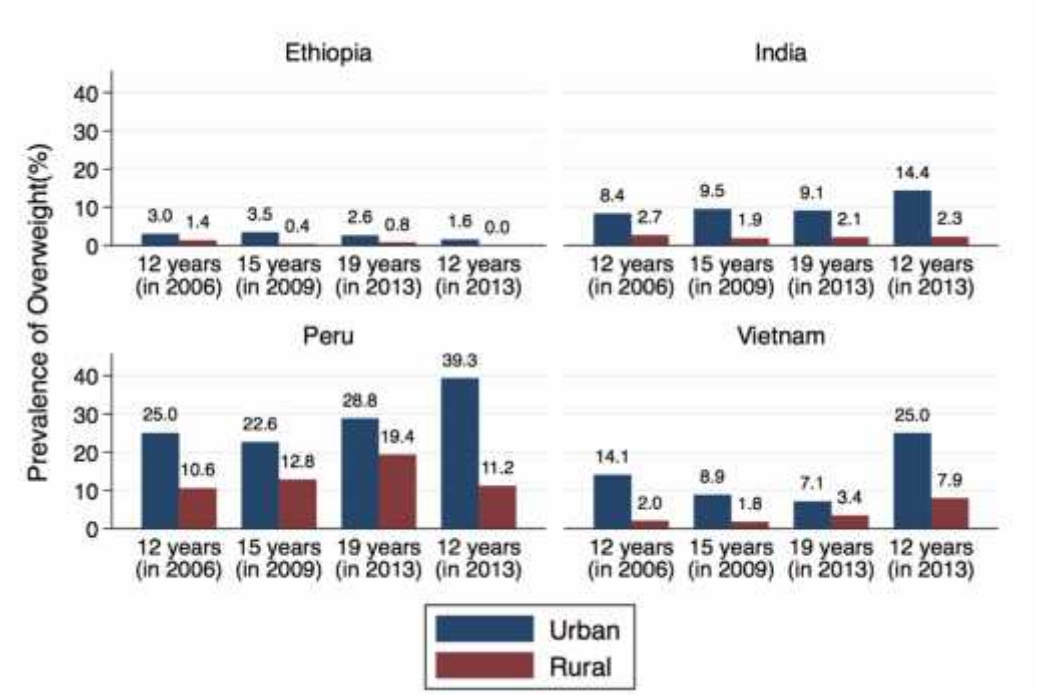


Notes: This figure presents the prevalence of thinness between urban and rural communities among adolescents in Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam from the Young Lives study. Thinness is an indicator of concurrent malnutrition, and it assumes the value of 1 if an adolescent's BAZ is below 2SD from the international reference standard (de Onis et al., 2007). The data report the prevalence of thinness for the older cohort, as measured at 12 (2006), 15 years (2009) and 19 years (2013), and the younger cohort at 12 years (2013).

Figure 11 presents prevalence of overweight and obesity at different ages and by urban and rural communities in the Young Lives study samples. This figure mirrors the previous one on prevalence of thinness: in this case, Peru and, to a lesser extent, Viet Nam have the largest prevalence of overweight and obesity in the sample, followed by India and, with very low prevalence, Ethiopia.

Overweight and obese youth were present in all the study countries, with urban communities bearing the largest burden of overnutrition in adolescents and youth. The comparison between the younger cohort (2006) and the older cohort (2013) at 12 years points to the rapid increase in overweight and obesity among the younger generations in urban, more than rural, areas. Ethiopia was the only exception to this trend, where overweight slightly fell from already low levels in both rural and urban areas. In the case of Peru, Viet Nam and India this increase in urban areas in a relatively short amount of time is remarkable: in the same urban communities in Peru, the prevalence of overweight and obese among 12-year-olds moved from 25 per cent in 2006 to 39 per cent in 2013 (a 56 per cent increase). Similarly, in Viet Nam and India the prevalence of overweight 12-year-olds almost doubled in urban areas in the same time span, although it started from lower levels than in Peru. In rural areas in Viet Nam, the prevalence of overweight 12-year-olds increased by almost three times between 2006 and 2013, while there was stability in prevalence in Peru and India. Across the full sample, boys were slightly more likely to be overweight than girls (3 per cent of boys, 2 per cent of girls). This finding was driven by Viet Nam, where boys were twice as likely to be overweight as girls (6 per cent of boys, 3 per cent of girls).

Figure 11. Prevalence of overweight by place of residence, age and cohort (Young Lives data)



Notes: This figure presents the prevalence of overweight and obesity between urban and rural communities among adolescents in Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam from the Young Lives study. Overweight and obesity is an indicator of overnutrition, and it assumes the value of 1 if an adolescent's BAZ is above 1SD from the international reference standard (de Onis et al., 2007). The data report the prevalence of overweight and obesity for the older cohort, as measured at 12 years (2006), 15 years (2009) and 19 years (2013), and the younger cohort at 12 years (2013).

These results echo the trends found in the wider literature (e.g. Christian and Smith, 2018), where the decrease in thinness in LMICs is much slower than the rise in overweight and obesity, widening the BMI distribution overall. It is worth noting that although India and Viet Nam have similar level and speed of structural and rural transformations, as indicated in Table 1, adolescent anthropometric status trajectories are substantially different from each other in the Young Lives cohorts. Detailed, country-specific follow-up analysis would be needed to understand the factors behind the emergence of these differences.

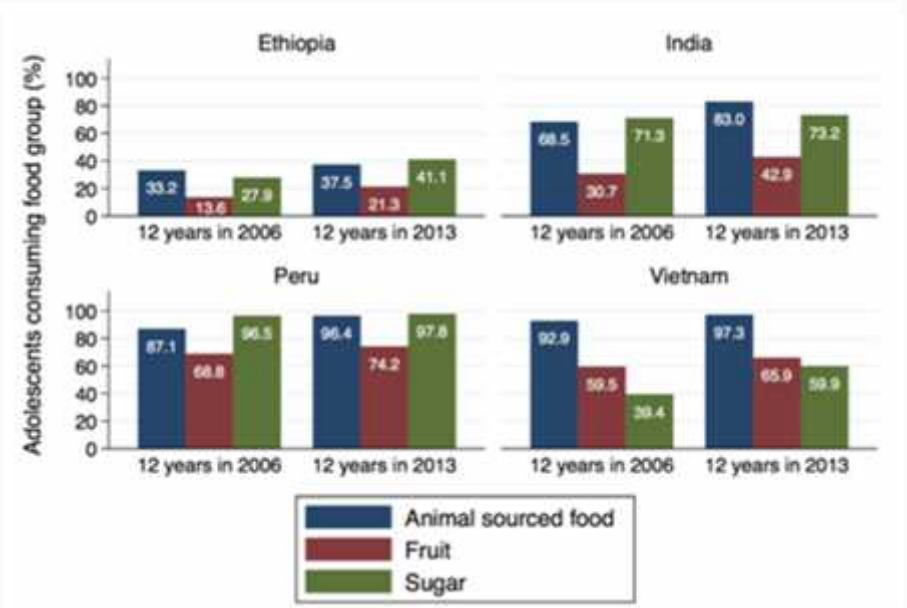
Next, figure 12 highlights the rapid shifts occurring in diets between among 12-year-olds in 2006 and 2013, rather than examining diets for different age groups as in the figures above. 4 The chart represents the share of adolescents that have reported consuming any of the following food groups in the previous day: animal source foods (e.g. meat, milk and dairy, fish, and eggs); fruits; and foods including added sugars. In other words, the chart shows how the diet of an average 12-year-old living in a specific community in each country has changed in the 8-year time span dividing the two cohorts.

Consumption of all of these food groups increased between 2006 and 2013 among 12-year-old across all countries, with consumption prevalence of these food groups being lowest in Ethiopia in both the time periods. Viet Nam saw the steepest increase in sugar consumption, followed by Ethiopia (Peru's baseline consumption levels were very high), while Indian cohorts' consumption of animal source foods and fruits rose most sharply among these four countries. It is possible that in India, school mid-day meal programmes may have influenced these consumption patterns; consumption of these foods

[4] For a similar investigation of shifts in diets between the older and the younger cohort 12-year-olds, see Aurino et al. (2017).

among adolescents appears to be much higher than reported in South Asia (Keats et al., 2018). Overall, no marked gender differences were evident between 12-year-olds in 2006 (older cohort). However, in 2013, girls appeared more likely to consume more of both added sugars and fruits than boys (sugars: 64 per cent of girls, 60 per cent of boys, $p<0.01$; fruits: 50 per cent of girls, 46 per cent of boys, $p<0.05$). For sugars, this difference was driven by adolescents in Ethiopia (44 per cent of girls, 37 per cent of boys, $p< 0.05$) and Viet Nam (63 per cent of girls, 56 per cent of boys, $p<0.05$). In all countries, girls tended to be eating fruit more frequently, but in the country-disaggregated data these gender differences were not statistically significant.

Figure 12. Prevalence of consumption of animal source foods, fruits and added sugars among rural 12-year-olds by cohort and country (Young Lives data)



Notes: This figure presents the prevalence of adolescents consuming different food groups in Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam from the Young Lives study. The graph reports the data for the older cohort, as measured at 12 years (2006), and the younger cohort at 12 years (2013).

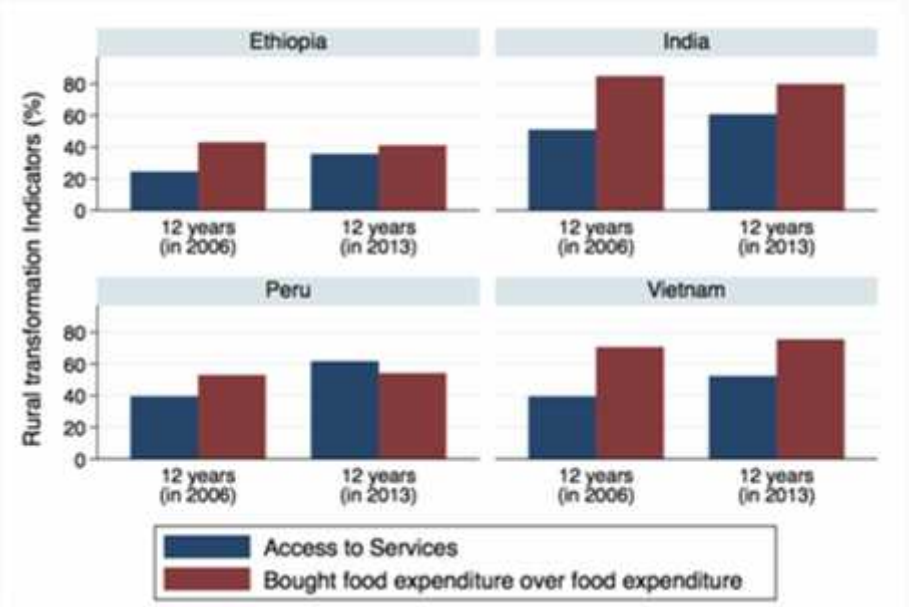
In summary, descriptive analyses of nutritional outcomes among Young Lives adolescents points to a diverse set of countries characterised by diverse stages in the nutrition transition:

- Peru (overweight and obesity) and Ethiopia and India (thinness) are on the opposite ends of this spectrum, followed by Viet Nam bearing the brunt of the double burden of malnutrition.
- Underweight is mostly a rural phenomenon and overnutrition predominantly prevalent in urban communities, although in Viet Nam overnutrition is rising fast in rural areas.
- There are disturbingly steep increases in overweight and obesity among 12-year-old adolescents. By contrast, there was no change (and in the case of Ethiopia, there was an increase) in the prevalence of thinness.
- Boys were, at the same time, more likely to be at the extreme ends of the BMI distribution. This finding was particularly evident in the case of thinness.
- An overall trend is increased consumption of animal source foods, fruits and added sugars across all countries.

7.3. Descriptive findings on rural transformation and food environments

Figure 13 provides a representation of changes in average access to services at community level – which we expect to improve with high level and speed of rural transformation – and share of bought food over total food consumption – our proxy for food environments – between 2006 and 2013 in the four countries. Average access to services changes across all countries, while on the contrary, the share of bought food was substantially stable over time. In India there was actually a decrease in this share, due, we speculate, to the role of public food security programmes that provided to household a fair share of their basic food staples.

Figure 13. Changes in access to services and share of bought food at rural community level in 2006 and 2013, by country, (Young Lives data)



Notes: This Figure provides differences in average access to services and share of bought food at the community level between 2006 and 2013.

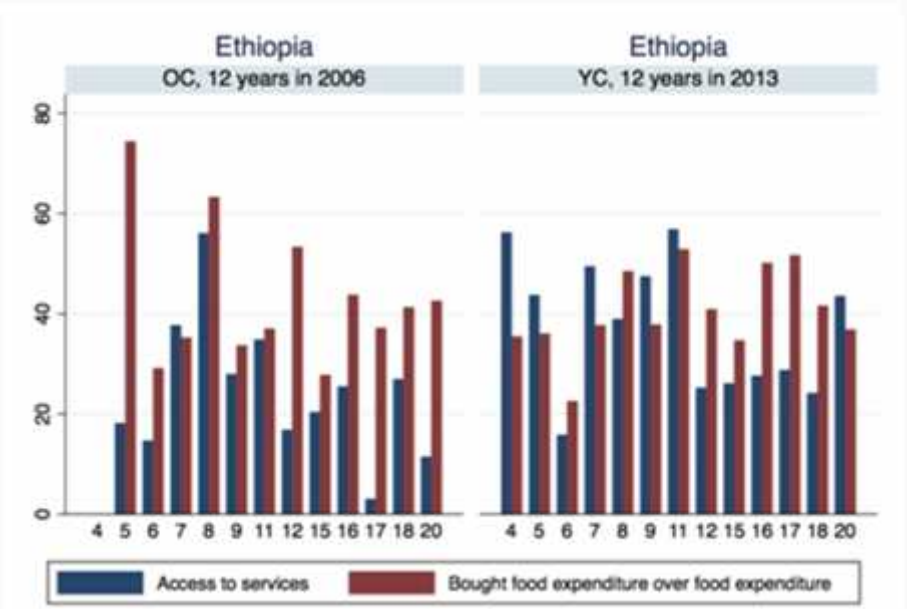
These above averages, however, mask substantial heterogeneity across different rural communities within each country. An example is figure 14, which shows change in access to services and proportion of bought food over total food expenditures in the rural communities in the Ethiopian sample. The figure highlights remarkable variation in the changes of both indicators across communities, particularly in the access to services. We observed similar heterogeneity across communities in other countries.

Finally, figure 15 explores patterns of household expenditures on different food groups for sample households in 2006 and 2013. As opposed to the previous chart, which was focused on adolescent consumption patterns on the previous day, these data focus on cross-cohort changes in consumption patterns at the household level for rural samples for different food groups. Again, there was substantial heterogeneity by country. In Ethiopia, patterns of food expenditure did not change particularly in the eight years separating one cohort from the other: the largest share of sample households' budgets was devoted to staple foods, followed by all remaining groups (e.g. oil, sugars), followed by animal source foods and vegetables. By contrast, in the other countries there were marked shifts from staple food expenditures towards increases in the share of the budget allocated to purchases of animal source foods. Also, in India, the reduction in staple food expenditures was counterbalanced by an increase in the share of expenditures on vegetables, while in Peru there were increases in the share of expenditures on fruit.

Taken together, these findings suggest that:

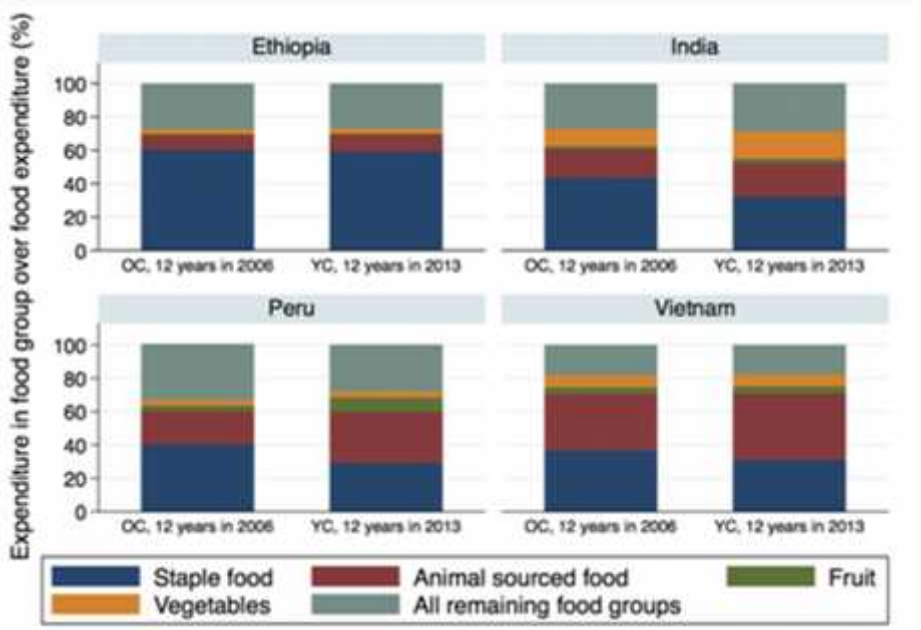
- There was important expansion in access to services, our key proxy indicator of rural transformation, in all study countries.
- Overall, there was remarkable heterogeneity across communities within the same country in the proxy indicators of rural transformation and food environments.

Figure 14. Changes in access to services and share of bought food for rural communities in 2006 and 2013, by community (Young Lives data for Ethiopia).



Notes: This Figure provides differences in average access to services and share of bought food at the community level between 2006 and 2013 in the Ethiopian rural sample.

Figure 15. Rural household food expenditure shares, by cohort and country (Young Lives data)



Notes: This figure presents shares of food expenditures over total food expenditure among rural households from the older cohort (OC) in 2006 and younger cohort (YC) in 2013 in Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam. Household food expenditures were measured in the month preceding the survey. Expenditures on staple foods include expenditures on cereals, roots and tubers; animal source foods include expenditure on meat, milk and dairy, fish and eggs. All remaining food groups include oil, sugar, processed foods and alcohol.

7.4 Multivariate analysis findings

So far, we presented descriptive findings on youth nutritional status and indicators of rural transformation and food environments in the four study settings. In Table 3 we explore the associations of proxy for rural transformation on youth nutrition outcomes on the pooled sample. [5] Full results reporting coefficients for control variables are reported in Supplementary Table 4.

Adolescents residing in communities with better access to services had higher BAZ (significant at 10 per cent level), and lower probability of thinness (significant at 10 per cent level). We did not find a statistically significant change in probability of being overweight. These adolescents were also more likely to report a higher dietary diversity score.

We did not find a significant association between the food environment proxy and anthropometry, but we observed positive associations between this variable and consumption of animal source foods and fruits in the last 24 hours in the pooled sample. This increase in animal source foods and fruits, but not overall dietary diversity score, is not surprising. Earlier analyses of this data show significant changes by individual food groups, especially in Viet Nam and India. While both the countries saw increases in consumption of animal source foods, in Viet Nam, in 2013, adolescents were less likely to consume foods cooked in oil; in India they were less likely to consumes pulses, legumes and nuts (Aurino et al., 2017).

Supplementary Table 4 shows that, coherently with the descriptive statistics, being male was strongly associated with lower BMI and chances of being underweight (-10 percentage points as compared to girls). Also, boys were less likely to eat fruits. Maternal education was positively associated with better

[5] There is wide heterogeneity in the correlations of access to services and proportion of purchased food over total food consumption by country (Ethiopia: =0.13; India: =-0.13; Peru: =0.05; Viet Nam: =0.42).

nutritional status, dietary diversity, and chances of eating animal source foods and fruits. Wealth index was only statistically significantly associated with consumption of animal source foods and fruits. This result may be explained by the correlation of wealth index with the community-level indicators of rural transformation. Compared with 12-year-olds, adolescents at 15 and 19 years had better BAZ, were less likely to be underweight, but also were significantly more likely to be overweight.

Overall, these results suggest that improving access to services, and broader rural transformation, may contribute to positive nutritional outcomes for youth through improvement in BMI and dietary quality. On the other hand, market access, as proxied by the food environment indicator, can enhance consumption of micronutrient-rich foods such as fruits and animal source foods. However, given the variation in the prevalence and pace of rural transformation in different communities, future country-specific research will be needed to understand in depth the relation between rural transformation, food environment and nutritional outcomes of youth.

Table 3. Markets and service access and nutritional outcomes among youth: OLS regressions (Young Lives rural sample, pooled cohorts in 2006, 2009 and 2013)

	BAZ	**Adolescent is thin**	**Adolescent is overweight or obese**	**Dietary diversity score**	**Ate animal source foods**	**Ate fruits**
Access to services at the community level	0.186*	-0.045*	0.006	0.181**	0.045	0.013
	(0.097)	(0.025)	(0.005)	(0.088)	(0.029)	(0.038)
% of expenditures on bought foods / total food expenditures at the community level	-0.074	0.025	0.007	0.015	0.076**	0.059*
	(0.079)	(0.021)	(0.005)	(0.069)	(0.031)	(0.031)
Observations	8,051	8,057	8,052	8,821	8,728	8,818

Notes: * p<0.10; ** p<0.05; *** p<0.01. Standardised beta coefficients with standard errors clustered at community level in parentheses. This table presents associations between rural transformation variables (access to services at the community level) and of food environments (share of bought food over food consumption at the community level) with BMI-for-age z-scores (BAZ); dietary diversity; thinness, which assumes the value of 1 if BAZ < -2SD from the international reference standard; overweight and obesity, which assumes the value of 1 if BAZ>1SD; consumption of animal source foods; and consumption of fruits. All models included the following covariates: adolescent's age in months; gender; maternal years of schooling; household's size; household wealth; and dichotomous variables for cohort and age groups.

8. Conclusions and implications

The aim of this paper was to unpack the role of rural transformation and the double burden of malnutrition among rural youth. Our study is the first one to track four decades of changes in BMI of youth and assess the correlations of these changes with rural transformation processes. We propose a unifying conceptual framework to aid this inquiry.

Overall, as noted in the wider literature (Galloway, 2017; Jaacks et al., 2015; NCD-RisC, 2017), thinness has reduced slowly but consistently across all regions; overweight and obesity increased in all regions but with varying rates.

Our descriptive analyses showed that indicators of rural transformation have important implications for the double burden. At lower levels of rural transformation, countries with the fastest speed of rural transformation saw the steepest increases in overweight and obesity, especially among younger age groups. Trends seem to suggest that more developed economies tend to be correlated with a shift from normal weight to overweight.

Countries with a low level of rural transformation, but transforming at fast speed, are also experiencing rapid shifts in foods available, with larger increase of fat and food supply, fruit and vegetable consumption, and sugar intake. The analysis of the household-level data from Ethiopia, India, Peru and Viet Nam shows an increase in consumption of all these food groups, but with important overall substitution effects. Given that several countries are in this typology (high/fast), to reap the youth dividend, our exploratory analyses suggest the importance of managing these concurrent rural transformation and food system changes to optimize nutritional outcomes of the youth. Insights from the Young Lives panel shows that such "nutrition-sensitive" rural transformation could include improvements in access to services which appears to reduce thinness and improve dietary diversity, without exacerbating overweight. Our results also show that improvements in food environments (an interaction between personal and external domains, which our indicator attempts to capture) as a key entry point for making rural transformation nutrition-sensitive. Policies that not only influence supply and market access (external food environment), but the interaction between the external and personal food environments (affordability, desirability and convenience) will play a crucial role. Managing changing agriculture productivity to ensure availability and affordability of nutrient-rich foods through one's own production and via markets should be a policy priority in guiding rural transformation with a nutrition- and youth-sensitive lens.

Changes in food supply trends within countries vary remarkably and are poorly explained by economic growth and food importation (Basu, 2015). Food supply changes were associated with domestic production, including domestic food production of internationally franchised products. This shows that countries, with prudent national policies, even in the globalized food system, can affect food systems and food environments in decisive ways.

Given the positive and negative impacts of rural transformation processes on the nutrition transitions of rural youth, policies need to focus on making these processes youth- and nutrition-sensitive. This means focusing not only on food supply and food trade, but how and what food is distributed and marketed and by whom, shaping food environments and thus food acquisition patterns of various segments of the population. It is important to understand how major drivers of structural and rural transformations, such as foreign direct investment in the agriculture and food sectors, trade regimes and consolidation of agri-food businesses impact food environments and, therefore, the dietary choices of rural youth and other segments of the population. In areas where investment by the agri-food industry is seen to be having deleterious effects of rural youth nutrition and health, strong public interest regulation may be needed. National governments need to consider a combination of fiscal policies such as taxation (e.g. taxing "unhealthy foods" such as sugar-sweetened beverages) and regulations to restrict marketing of nutrient-poor and highly processed foods to children and young people; monitoring of marketing and advertising of such foods and beverages; improvement in nutritional standards of school meals; and monitoring the outcomes of investments made by agri-food companies in helping communities to ensure that these investments do not have negative health, environmental, social and economic consequence. While voluntary regulations are gaining popularity, there is little evidence to date that conflicts of interest inherent in agri-food-industry self-regulation have been overcome successfully. To date self-regulation by the food industry appears to have largely failed to meet stated nutrition and health objectives. Regulatory and fiscal measures need to be combined with interventions to induce behaviour change for healthier eating through public health messaging and innovative behaviour change communication using social media and digital technology. There is clear evidence (e.g. from the analysis of Young Lives data) that access to public services can improve diet quality and nutritional status. So rural transformations should be conceptualized more broadly than sectoral changes in livelihoods. Access to services should be planned rather than considered as an outcomes of sectoral composition changes. It is by a clearer and evidence-led understanding of the pathways of impact of rural transformation processes on rural youth nutrition that "nutrition-sensitive" policies can emerge.

Tables and figures

Supplementary table 1. Countries by rural transformation typology

		Level of rural transformation	
		Low	High
Speed of rural transformation	Slow	Afghanistan, Benin, Bhutan, Bolivia (Plurinational State of), Burkina Faso, Burundi, Cambodia, Central African Republic, Gambia (The), Guinea-Bissau, Lao People's Democratic Republic, Madagascar, Malawi, Nepal, Togo, Uganda, Zambia (17)	Belize, Colombia, Costa Rica, Egypt, El Salvador, Guatemala, Kyrgyzstan, Namibia, Pakistan, Panama, Peru, Philippines, Thailand, Tunisia (14)
	Fast	Bangladesh, Cameroon, Ethiopia, Guinea, India, Kenya, Lesotho, Mali, Mozambique, Myanmar, Niger, Rwanda, Senegal, Sierra Leone, Sri Lanka, United Republic of Tanzania (16)	Brazil, China, Dominican Republic, Ecuador, Eswatini, Ghana, Honduras, Mexico, Morocco, Nicaragua, Nigeria, Paraguay, South Africa, Tajikistan, Turkey, Uzbekistan (16)

Resource-rich countries

Algeria, Angola, Azerbaijan, Congo, Democratic Republic of the Congo, Equatorial Guinea, Iran (Islamic Republic of), Iraq, Kazakhstan, Liberia, Mauritania, Mongolia, Suriname, Timor Leste, Turkmenistan (15).

Supplementary Table 2. Rural youth nutritional status in the Young Lives sample, by country

Panel A. Ethiopia

	Older cohort (born 1994-1995)			**Younger cohort (born 2001-2002)**
	12 years (in 2006)	15 years (in 2009)	19 years (in 2013)	12 years (in 2013)
Dietary diversity score	3.352 (1.086)	3.663 (1.048)	3.895 (0.997)	3.856 (0.960)
Ate animal source foods, %	33.4 (0.472)	39.7 (0.490)	36.7 (0.483)	37.5 (0.484)
Ate fruits, %	13.5 (0.342)	11.7 (0.322)	12.5 (0.331)	21.3 (0.409)
Ate added sugars, %	27.9 (0.449)	35.1 (0.478)	53.2 (0.500)	41.1 (0.492)
BAZ	-1.763 (1.067)	-1.948 (1.148)	-1.272 (1.096)	-1.988 (0.905)
Thin, %	39.7 (0.490)	49.6 (0.500)	26.2 (0.441)	45.9 (0.499)
Overweight or obese, %	1,21 (0.110)	0 (0)	0.8 (0.0896)	0 (0)

Panel B. India

	Older cohort (born 1994-1995)			**Younger cohort (born 2001-2002)**
	12 years (in 2006)	15 years (in 2009)	19 years (in 2013)	12 years (in 2013)
Dietary diversity score	4.194 (0.922)	4.256 (0.871)	4.236 (0.888)	4.296 (0.880)
Ate animal source foods, %	68.7 (0.464)	83.7 (0.370)	81.5 (0.389)	83.0 (0.375)
Ate fruits, %	30.7 (0.462)	30 (0.459)	39.2 (0.489)	42.9 (0.495)
Ate added sugars, %	71.7 (0.451)	75.7 (0.429)	72 (0.450)	74.5 (0.436)
BAZ	-1.608 (1.184)	-1.384 (1.164)	-1.155 (1.044)	-1.598 (1.234)
Thin, %	37.2 (0.484)	29.9 (0.458)	20.4 (0.403)	37.8 (0.485)
Overweight or obese, %	1.68 (0.129)	1.8 (0.133)	2.23 (0.148)	2.14 (0.145)

Panel C. Peru

	Older cohort (born 1994-1995)			**Younger cohort (born 2001-2002)**
	12 years (in 2006)	15 years (in 2009)	19 years (in 2013)	12 years (in 2013)
Dietary diversity score	4.669 (1.285)	5.400 (1.160)	4.887 (1.161)	5.302 (1.037)
Ate animal source foods, %	87 (0.337)	94.2 (0.235)	93.5 (0.248)	96.4 (0.187)
Ate fruits, %	68.6 (0.465)	84.5 (0.363)	80.6 (0.398)	73.8 (0.440)
Ate added sugars, %	96.4 (0.186)	99.4 (0.0803)	96.8 (0.178)	97.8 (0.147)
BAZ	1.45 (0.783)	8.61 (0.871)	3.48 (0.746)	4.02 (0.863)
Thin, %	1.18 (0.108)	1.29 (0.113)	0 (0)	1.41 (0.118)
Overweight or obese, %	10.1 (0.302)	12.9 (0.336)	19.4 (0.398)	11.3 (0.317)

Panel D. Viet Nam

	Older cohort (born 1994-1995)			Younger cohort (born 2001-2002)
	12 years (in 2006)	15 years (in 2009)	19 years (in 2013)	12 years (in 2013)
Dietary diversity score	4.538 (1.014)	4.670 (0.919)	4.130 (1.229)	4.059 (1.232)
Ate animal source foods, %	92.9 (0.257)	96.4 (0.187)	98 (0.140)	97.2 (0.164)
Ate fruits, %	59.4 (0.491)	59.1 (0.492)	60.5 (0.490)	66.1 (0.473)
Ate added sugars, %	39.3 (0.489)	65.9 (0.474)	59 (0.493)	59.9 (0.490)
BAZ	-1.146 (0.986)	-0.926 (0.993)	-0.727 (0.996)	-0.779 (1.212)
Thin, %	18.4 (0.388)	14.5 (0.352)	10 (0.301)	15.6 (0.363)
Overweight or obese, %	1.90 (0.137)	1.8 (0.133)	3.50 (0.184)	7.91 (0.270)

Notes: Mean with SD in parentheses. This table presents select nutritional outcomes for rural adolescents from the two cohorts of the Young Lives sample from Ethiopia, India (Andhra Pradesh and Telangana), Peru and Viet Nam. BMI-for-age z-scores (BAZ) is an indicator of contemporaneous nutritional status, while height-for-age z-scores (HAZ) measures the history of health inputs. Both were calculated on the basis of the WHO International Reference Standards (de Onis et al. 2007). Starting from those, three dichotomous variables were generated: thinness, which assumes the value of 1 if BAZ < -2SD from the international reference standard; overweight and obesity, if BAZ > 1SD; and stunting, if HAZ < -2SD. Individual dietary diversity is a measure of an adolescent dietary variety and proxy for nutritional adequacy. Three dichotomous variables of whether the adolescent has eaten any animal source foods (meat, milk and dairy, fish and eggs), fruits and added sugars in the previous day were also generated.

Supplementary table 3. Descriptive statistics of covariates, rural sample only

	Older cohort (born 1994-1995)			**Older cohort (born 2001-2002)**
	12 years (in 2006)	**15 years (in 2009)**	**19 years (in 2013)**	**12 years (in 2013)**
Child's age in months	147.2 (4.252)	180.2 (3.956)	229.2 (4.453)	144.9 (3.969)
Child is male	0.506 (0.500)	0.507 (0.500)	0.566 (0.496)	0.527 (0.499)
Mother's years of educ	3.484 (3.972)	3.830 (4.103)	4.107 (4.169)	3.985 (3.978)
Wealth index	0.376 (0.190)	0.460 (0.194)	0.503 (0.179)	0.479 (0.179)
Household size	5.601 (1.947)	5.338 (1.975)	4.808 (1.957)	5.184 (1.739)

Notes: Mean with SD in parentheses

Supplementary table 4: Markets and service access and nutritional outcomes among youth: OLS regressions, full results (Young Lives rural sample, pooled cohorts in 2006, 2009 and 2013)

	BAZ	Adolescent is thin	Adolescent is overweight or obese	Dietary diversity score	Ate animal source foods	Ate fruits	In last 24hrs did child eat sugar/honey
Bought food consumption over food consumption at sentinel site level	-0.074	0.025	0.007	0.015	0.076**	0.059*	0.094***
	(0.079)	(0.021)	(0.005)	(0.069)	(0.031)	(0.031)	(0.027)
Access to services at community level	0.186*	-0.045*	0.006	0.181**	0.045	0.013	0.073**
	(0.097)	(0.025)	(0.005)	(0.088)	(0.029)	(0.038)	(0.032)
Child is male	-0.268***	0.106***	0.010*	-0.019	0.002	-0.028**	-0.025*
	(0.046)	(0.016)	(0.005)	(0.025)	(0.010)	(0.013)	(0.015)
Child's age in months	-0.019***	0.004*	-0.002**	0.000	0.001	-0.002	-0.006***
	(0.006)	(0.002)	(0.001)	(0.005)	(0.002)	(0.002)	(0.002)
Mother's years of education	0.055***	-0.014***	0.004***	0.041***	0.020***	0.033***	0.005
	(0.011)	(0.003)	(0.001)	(0.008)	(0.003)	(0.003)	(0.004)
Wealth index	0.216	-0.106	0.021	0.285	0.281***	0.130*	-0.074
	(0.254)	(0.069)	(0.019)	(0.171)	(0.074)	(0.077)	(0.083)
Household size	-0.028*	0.011**	0.001	0.012	-0.000	0.007	0.006
	(0.015)	(0.005)	(0.001)	(0.011)	(0.005)	(0.005)	(0.005)
Younger cohort	-0.170*	0.084***	0.012	-0.169	0.013	0.055	0.054
	(0.092)	(0.025)	(0.009)	(0.105)	(0.032)	(0.042)	(0.039)
Categorical variable for child's age = 1, 15 years (in 2009)	0.573***	-0.096	0.050**	0.090	0.011	0.045	0.299***
	(0.190)	(0.065)	(0.025)	(0.158)	(0.057)	(0.082)	(0.094)
Categorical variable for child's age = 2, 19 years (in 2013)	1.591***	-0.349**	0.138**	-0.129	-0.044	0.137	0.545***
	(0.471)	(0.164)	(0.062)	(0.372)	(0.141)	(0.190)	(0.190)
Constant	1.574*	-0.385	0.252**	3.955***	0.461*	0.492	1.430***
	(0.921)	(0.293)	(0.111)	(0.796)	(0.263)	(0.369)	(0.344)
Observations	8,051	8,057	8,051	8,821	8,728	8,818	8,819
R-squared	0.085	0.057	0.020	0.076	0.209	0.128	0.090

Notes: * p<0.10; ** p<0.05; *** p<0.01. Standardised beta coefficients with standard errors clustered at community level in parentheses. This table presents associations between rural transformation variables (access to services at the community level) and of food environments (share of bought food over food consumption at the community level) with BMI-for-age z-scores (BAZ); dietary diversity; thinness, which assumes the value of 1 if BAZ < -2SD from the international reference standard; overweight and obesity, which assumes the value of 1 if BAZ > 1SD; consumption of animal source foods; consumption of fruits; and consumption of added sugars.

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