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Income Versus Prices: How Does The Business Cycle Affect Food (In)-Security?

Christian Bogmans, Andrea Pescatori and Ervin Prifti

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Abstract

We study how two aspects of food insecurity -caloric insufficiency and diet composition- are affected by aggregate economic fluctuations. The use of cross-country panel data allows us to adopt a global prospective on the identification of the macroeconomic determinants of food insecurity. Income shocks are the most relevant driver of food insecurity, displaying high elasticities at the early stages of economic development. The role of food price shocks is more limited. Social protection has a direct effect and mitigates the impact of income shocks. Effects are highly heterogeneous across a range of structural characteristics of the economy, highlighting the role of distributional aspects and of food import dependency.

JEL Classification Numbers: O11, Q1, I38

Keywords: Food insecurity; growth; food prices; social protection; diet and health

1 Introduction

As the Covid-19 pandemic induced the worst recession since World War Two, anecdotal evidence emerged about the quickly worsening food security situation of millions of people around the world. A reduction in income from job losses due to the sudden stop of economic activity combined with food scarcity and higher food prices from supply chain disruptions meant that millions of households descended into poverty and subsequently might have had to reduce the quality and quantity of food consumed. While the relationship between poverty and macroeconomic indicators has been widely studied, evidence on how food insecurity would be affected by the pandemic-induced macroeconomic downturn remained anecdotal or restricted to the grey literature, at best (Meyer and Sullivan, 2011; FAO, 2020). The aim of this paper is to fill the gap of rigorous evidence on the short-term variations of food (in)security in response to business cycle fluctuations and explore the role of relevant policy instruments to address jumps in food insecurity. The literature on the micro-level determinants of household food security has abundantly documented the role of household income, education, ethnicity, access to social welfare and so on (Gundersen et al., 2011; Akter and Basher, 2014; Tiwari et al., 2016). On the other hand, the macro-drivers of national food security have received much less attention. Few studies have looked into the effects of aggregate economic factors like GDP or the general level of food prices on food insecurity in single countries and only a handful have done so at a global level using cross-country data (Gregory and Coleman-Jensen 2013; Nord et al., 2014; Heady, 2013; Soriano and Garrido; 2016). To the best of our knowledge this is the first paper to study food insecurity using a cross-country approach and considering jointly manifestations of quantitative sufficiency and qualitative adequacy of diets.

Specifically, we quantify the impact of real GDP per capita, food inflation, social protection expenditure and initial conditions on the prevalence of undernourished (PoU) and on diet composition. Identifying in an integrated framework the relative strength of income and food inflation, the main determinants of food purchasing power, as well as of income support measures like social protection, has important policy implications for the safeguard of food security.

The macro-relevance of food (in)security becomes clear if we consider its significant long-run repercussions on economic development. Undernourishment and poor diet composition, especially during childhood, can have negative effects on physical and cognitive development, limiting educational attainment and lifelong earning potential - hence, perpetuating inequality by keeping people in a poverty trap (Victora et al., 2008; Atinmo et al., 2009). At the aggregate level, if the phenomenon is widespread across the population, it can reduce a country's human capital accumulation and labor productivity, thus, its economic growth potential (Fogel, 2004). More broadly, as it relates to basic human needs, food (in)security has played an important role throughout history by catalyzing political change and triggering conflicts. Examples are abundant, from the French Revolution - when Marie-Antoinette of Habsburg's lighthearted invitation to her subjects to switch to brioches in absence of bread served as the spark to ignite the initial riots - to the first world food crisis of modern times, between 1972 and 1975, that led to two million hunger-related deaths and the violent toppling of several governments and, finally, to the 2010-11 Arab Spring when food protests lit the chain of social upheavals that became known in the region as Hunger Revolutions (Bellemare, 2014, Gerlach, 2015).

Indeed, in recognition of its economic and social repercussions, the importance of food security has been formally recognized by the international community by inscribing it in the Sustainable Development Goal number 2 of the United Nations (aka Zero Hunger), setting 2030 as the target for eliminating undernourishment - reducing more than 60 million of undernourished per year, arguably a daunting task.[1]

We assembled data from several sources to form a longitudinal dataset covering 142 countries for a period of two decades (2001-2018). Our analysis relies on panel data methods that address both country unobserved heterogeneity and various sources of endogeneity. We find that food insecurity manifests considerable short-term sensitivity to business cycle fluctuations. For a one percent growth in real GDP per capita the share of undernourished falls by 0.75 percent on average across countries. Income changes also drive diet reallocation, as households react to recessions by replacing expensive calories sources (e.g. proteins) with cheaper ones (e.g. carbs). Food prices play a more modest role compared to real income as their effect on undernourishment is four to five times smaller, once we correct for the different standard deviations of the two covariates. Social protection spending has a direct effect on reducing undernourishment although the magnitudes are small and in the same order as food inflation. Finally, although countries that start out with higher levels of undernourishment show higher rates of reduction, the pace is very slow, providing little, if any, evidence of cross-country convergence in undernourishment levels in the absence of GDP per capita convergence. Hence, economic growth is by far the most important factor in eliminating global hunger and changing diets.

In analysing the heterogeneity of the growth effects along structural characteristics of the economy, we find that growth plays a crucial role in eliminating hunger and changing diets at the early stages of development, while its role fades away as countries grow richer. Further, growth is much more effective in curbing undernourishment in more inclusive economies where the bottom 20 percent of society holds a higher share of national income. Social safety nets, being a form of income support for households in moments of hardship and a countercyclical stabilizer at the macro level, also play an important role in containing the negative dietary impacts of economic crises. To the extent that social protection spending helps keep inequality under check and foster inclusiveness through its redistributive role, it can further strengthen the impact of growth on hunger reduction. Our results are robust to a wide variety of sensitivity checks related to our identifying and functional form assumptions, covariate specification and sample composition.

[1]The latest reminder of the importance of food security both from a research and policy perspective came when the 2020 Nobel Peace Prize was awarded to the United Nations World Food Programme for its efforts to combat hunger.

The novelty of our study can be appreciated from several points of view. First, the role of the broader macroeconomic conditions in relation to food insecurity have been studied by analyzing individual indicators in isolation. Here we take an integrated approach and simultaneously consider the major macro determinants. Second, we study both quantitative and qualitative aspects of food insecurity to capture the varying degrees of severity of the phenomenon and the connection between quantitative sufficiency and qualitative adequacy of diets. Third, we use objective aggregate indicators to capture national food security instead of subjective micro-level indicators that offer less scope for cross-country comparability due to their perception-based nature. Fourth, our empirical strategy explicitly addresses the problem of endogenous co-variation among food insecurity and its determinants, after recognizing the potential for reverse causality even in the short run. We show that ignoring this issue leads to downward biased estimates of the income elasticity of undernourishment. Fifth, while research on poverty convergence is abundant, this is the first paper to study cross-country convergence in hunger and diet composition. Sixth and finally, having put in a single model a set of macro determinants whose choice is theory driven, we are also the first to consider the role of social protection in food security from a macro point of view, for which we found no prior work.

The paper is organized as follows: section 2 reviews the literature, while section 3 presents a simple conceptual framework that provides the theoretical underpinning of our analysis. Section 4 documents the data and describes our main variables, followed by a presentation of the empirical strategy in section 5. Finally, section 6 presents results from the main approach and the robustness analysis, while section 7 discusses the findings and draws some policy-oriented implications.

2 Literature Review

Most research on food insecurity focuses on its socio-demographic determinants at the micro level, highlighting the role of household income in combination with the household demographic structure, the educational attainment of its members, access to social protection and covers country contexts in both the developed (Borjas, 2004; Leete and Bania, 2010; Gundersen et al., 2011) and the developing world (Hadley et al. 2012; Kumar and Quisumbing, 2013; Smith et al., 2000; Grimaccia and Naccarato, 2019).

Results from a smaller number of studies focusing mostly on the US, seem to indicate that food insecurity is very sensitive to variations in the business cycle and the overall economic context (Bartfeld and Dunifon 2006; Gundersen et al., 2014). Nord et al. (2014) find that macroeconomic conditions explain more than 80% of the national food insecurity variations in the US, with a 1 percentage point increase in unemployment leading to an almost 5% increase in the share of food insecure people.[2]

[2]The USDA uses subjective indicators to measure the share of food insecure people. These are those that answer yes to the question “Were you ever hungry but did not eat because you couldn’t afford enough food?”.

Only a handful of studies, focusing on the effect of aggregate income and the general level of food prices on food insecurity measures, have taken a cross-country perspective. This part of the literature, although the closest to our study, differs in either of the following important aspects: use of subjective experiential measures of food insecurity, different geographic and temporal coverage, long-term perspective and, most importantly, none of the studies addresses the issue of possible endogeneity of the explanatory variables. The first two studies use subjective experiential measures of food insecurity and cover the 2005-2009 period. Heady (2013) studies the impact of the 2008 global food crisis using cross-country survey data from 69 countries on the Food Insecurity Experience Scale (FIES). Contrary to us, their study finds a global income elasticity of food insecurity of around 0.2% for every 1% increase in real GDP per capita, while relative food inflation has no discernible impact. The study finds no variation of the effects of GDP growth and food inflation across countries' stages of economic development. Verpoorten et al. (2013) analyze data on subjective food insecurity experience in 18 Sub-Saharan African countries.[3] Improvements in food security over time were positively correlated with GDP per capita growth, while higher consumer food prices hamper food security. Experience-based subjective measures of food insecurity classify as food-insecure different groups of people compared to objective measures based on the sufficiency of calorie consumption, hence the different results (Broussard and Tandon, 2016). The cross-country comparability of such measures is also lower, because they depend on a sense of deprivation that is defined based on cultural and even personal values and levels of endurance, which limits their utility to more restricted cultural contexts (Webb et al., 2006). The next two studies use objective measures of food insecurity given by the PoU and study its long-term determinants between 1991 and 2013 on distinct samples of countries and focusing on different contextual variables. Soriano and Garrido (2016) investigate whether access to education, health and water together with economic growth affect undernourishment in 27 developing countries, finding that a 1% increase in GDP per capita significantly reduces undernourishment by 0.29%. Eini-Zinab et al. (2020) cover 76 countries and focus on different macro-context variables. Finding overlapping time trends of the PoU across income quartiles, the study concludes there is no significant relationship between national income and undernourishment, although the Gini coefficient, literacy rates, child mortality and the Human Development Index are found to affect undernourishment. Our take is that these variables are simply mediating the effects of the primary cause, which is GDP per capita.

Our work is also related to the literature on the relationship between welfare programs and food insecurity. Most of the research here focuses on how access to specific social protection programs (e.g. cash/food transfers, unemployment benefits) affects household food security, whereas the effect of social protection as a feature of the policy environment

The average PoU is statistically not significant from zero in the USA.

[3]The question on food insecurity is formulated as follows: 'Over the past year, how often, if ever, have you or anyone in your family gone without enough food to eat? 0 = Never, 1 = Just once or twice, 2 = Several times, 3 = Many times, 4 = Always'.

have received little to no attention at all (Schmidt et al., 2016; Bartfeld, 2017). Borjas (2004) shows that subjective measures of food insecurity increased as access to social welfare programs in the US declined as a result of policy reforms. Bitler et al. (2020) show that the main reason for the stark increase in food insecurity in the US amidst the Covid-19 crisis can be traced down to the limited coverage and scope of the social protection system. The part of the literature focusing in developing countries, consistently finds that participating in social assistance programs greatly improves food security (Ruiz -Arranz et al., 2002; Miller et al., 2011; Tiwari et al., 2016).

Lastly, we also contribute to the branch of the literature that looks into dietary changes in response to economic shocks. Dominated by micro studies, the focus in this branch has been on how households use food-based coping strategies to face income or food price shocks. Some studies show that households can keep calorie levels in the face of food price increases or income losses by moving to cheaper foods. Jensen and Miller (2008) find that an increase in the price of specific food items led to no reduction in calories among poor households in rural China but households re-balanced their diets by moving away from more expensive foods. Similarly, D'Souza and Jollife (2013) show that during an episode of wheat price increases in Afghanistan, households that were already consuming minimum levels of calories did not reduce caloric intake, but those with higher levels of consumption did. Overall, dietary diversity decreased, leading the researchers to conclude that the poorest households sacrifice diet quality to maintain calorie sufficiency. Symmetrically, when prices decrease or incomes rise, household substitute staples for better tasting and more nutritious foods. Torlesse et al. (2003) show that when rice prices fell in Bangladesh, households did not consume more of it but increased non-rice food expenditures. We expand this branch of the literature by studying cross-country patterns of aggregate diet composition, how these evolve and react to common macro factors.

3 Conceptual Framework

According to a widely accepted definition originating from the United Nations, food and nutrition security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. Although the term that combines food and nutrition security concepts in an integrated way has gained popularity, it is important to distinguish the two since here we focus only on food security, or the lack thereof. Food security is a function of availability of adequate food in terms of quantity and quality and the people's ability to afford it at all times. When one or more elements of the definition of food security are missing, shares of population slide into food insecurity. While, nutrition security concerns also aspects of food utilization and is a function of a broader set of factors, including access to health services, healthy environment, water and hygiene as well as caring practices (Frankenberger et al. 1997).

From the point of view of its macroeconomic determinants food (in)security depends on the supply of food (i.e., availability) and households' demand for food (i.e., access). At the national level, food availability depends on the abundance of per capita food supplies from domestic production, stocks and imports of food. A true lack of food that would force a benevolent "social planner" to rationing is rarely a concern. History has shown that food is almost always available to those with buying power (Wiggins et al., 2009)—Amartya Sen observed that even in the severe Bengal famine of 1943 food was available (Tweeten, 1999). We, thus, focus on changes in domestic food price inflation to capture food supply shocks. It is a price increase in relation to wages that is relevant for our analysis, not a generalized increase in the price level, since only changes in the relative price of food will prompt changes in food consumption (Doepke and Scheider, 2006; Laborde et al., 2013). It is also important to distinguish between the short and long run effect of prices. In the medium to long run, an increase in food prices will trigger a supply response with more food being produced and agricultural wages and farm incomes rising which may result in improvements in food security. In the short run, the supply response is likely to be very limited considering the production lag in agriculture and the infrequent planting decisions. As a result, an increase in food prices caused by an external shock (e.g. bad weather, pandemic) should have a negative impact on food security regardless of the share of net food buyers or sellers in the country.

Food access, instead, relates to affordability and, for given food prices, "improved food security stems directly from a set of government policies that seeks rapid economic growth with improved income distribution" (Timmer, 2000; Shane et al., 2000). In other words, for a given level of food prices an increase in real income will raise purchasing power and lead to an improvement in food security by allowing consumers to consume more calories and switch to better and more diversified diets. A higher income implies also that a smaller share of it is spent on food and a larger buffer is available to absorb possible negative shocks in purchasing power. However, economic growth does not automatically translate into improved food security. Certain attributes of growth, like inclusiveness - or how much the poor and those most vulnerable to food insecurity participate in the benefits of economic growth - are important. In this respect, social protection has a crucial role to play amongst all policy instruments. First, it has a direct impact on food security by integrating household income in moments of distress (illness, unemployment) and reducing its variability over time. At the aggregate level, being a countercyclical measure, social protection spending will tend to stabilize income growth (Gruber 1997; Blundell and Pistaferri, 2003). Second, social protection can contribute to make growth more inclusive, and hence more effective in curbing food insecurity, in two ways: by implementing a partial redistribution of the fruits of growth and by addressing market failures that hit disproportionately the poor. In the latter case, social protection, as a stable source of liquidity, enables access to economic opportunities for the poor by easing credit and risk constraints which prevent entrepreneurial investments.

Finally, there is interdependence among real income, food price and social protection. Higher GDP per capita allows higher aggregate investments in social protection, which in turn fuels growth, as a component of aggregate spending. Further, increases in GDP are associated with higher demand for food and consequently higher prices.

There can be three manifestations of food insecurity with increasing degrees of severity: worry about food, inadequate diet quality and insufficient calorie intake (Wilde, 2011; Coates, 2013). Economic models have focused on the latter manifestations, since the former concerns inner subjective aspects that depend on perception, while the other two can be measured externally through objective indicators. Moreover, these two manifestations are inter-related as they materialize while utility-maximizing individuals move up or down the underlying continuum of food (in)security in response to income and food price shocks (Jensen and Miller, 2010). When an individual is below the minimum calorie threshold there is a severe disutility from the physical and psychological discomfort of feeling hungry. As a result, the marginal utility of extra calories is very high for calorie-deprived and resource-constrained individuals, leading them to acquire the cheapest available source of calories, typically cereals, roots and tubers. As more favorable combinations of income and food prices lift individuals above subsistence calorie levels, the marginal utility of extra calories declines rapidly and they substitute away from staples, introducing better tasting and more expensive foods, like meat, fish and fruits. Hence, an inverse S-shaped curve can be hypothesized for the relationship between the share of dietary calories derived from staples and real income, whereby it is first constant when the individual is calorie-deficient then starts declining rapidly until it flattens again at some minimal level of the staple that cannot be eliminated from diets. Conversely, consumers will increase staples in order to keep a sufficient calorie intake before descending into insufficient calorie consumption, in case of a negative shock to their purchasing power.

4 Data and Descriptive Statistics

From a measurement perspective, we focus on objective manifestation of food insecurity related to qualitative adequacy and quantitative sufficiency of diets (Wilde, 2011). To capture aspects of diet quality, we use the share of dietary energy from cereals, tubers and roots and the average supply of animal protein, mostly from meat and fish, measured in grams per capita per day. For the most severe manifestation of food insecurity related to insufficient caloric intake we use the Prevalence of Undernourished (PoU). The PoU is given by the share of a country's population whose habitual food intake is insufficient to conduct an active and healthy life. Ideally, the PoU would be estimated through a bottom-up approach by counting the number of individuals in a representative sample that fall below the undernourishment threshold. However, this is unfeasible, since individual dietary intake surveys are too costly, and the undernourishment threshold is unobservable for the single individual and has to come from assumptions in any case (Jensen and Miller, 2010). A top-down approach proceeds by assuming a parametric form for the distribution of daily dietary energy intake in the population so that only two or three parameters that fully characterize the distribution need to be estimated. The share of undernourished people in a country is then estimated as a cumulative probability of being below the minimum dietary energy requirements (MDER), i.e., the undernourishment threshold. More formally, $PoU = \int_{x<MDER} f(x|\theta)\, dx$ where $f(x|\theta)$ is the caloric intake distribution and θ includes the mean, the coefficient of variation and a skewness parameter. The mean is estimated every year from aggregate data on national food utilization accounts or from household survey data, when these are available. The other two parameters and the MDER are estimated from micro data less frequently. The literature has highlighted several limitations of the PoU, due to its top-down and aggregate approach. These relate to the quality of the national food accounts data, the arbitrariness of the choice of the parametric distribution, the choice of a single undernourishment threshold for the whole country and the lack of information on the severity of food insecurity.

The main competitor of the PoU is the Food Insecurity Experience Scale (FIES) that overcomes the feasibility constraints faced by the PoU, but has its own shortcomings. Being an experiential indicator, the FIES does not require a costly dietary intake section in the survey questionnaire and the assumption of undernourishment threshold. The FIES is based on eight binary questions that ask individuals about self-assessed food-related behaviors and subjective experiences associated with increasing difficulties in accessing food. The FIES has not been free of criticism either, most of which questions the comparability of perceived hunger experience across different individuals, countries and cultural contexts (Grimaccia and Naccarato, 2019). Moreover, Barrett (2010) points out that since most food insecurity is seasonal or related to episodes of unemployment or ill-health, perception-based subjective measures like the FIES may lead to overestimates of food insecurity compared to insufficient-intake measures like the PoU.

Although there has been a long debate in the literature highlighting the advantages and the limitations of both indicators, we opt for the PoU as an objective and aggregate measure of national food insecurity (Carletto et al., 2013; Caffiero et al., 2014). The PoU has been selected by the Food and Agriculture Organization of the United Nations to track progress towards the achievement of zero hunger by 2030 at a global level and has been released yearly for all countries from 2001 onward. From a practical point of view, our preference for the PoU is based also on its much longer time coverage, spanning almost two decades, while the FIES is available only for three waves. This makes the PoU more suitable for our analysis of how food insecurity varies with business cycle fluctuations.

Our set of control variables comes from several sources. Data on GDP, social protection expenditure and food inflation come from the IMF and the World Bank. We use real GDP per capita measured in 2017 PPP dollars. Social protection expenditure includes current in-kind or cash transfers to households intended to provide for the needs that arise from social risks. They fall mostly under two broad categories: social security (sickness, invalidity, maternity leave, unemployment benefits, retirement pension) and social assistance. The latter includes those transfers made to households either regardless of participation to social security schemes as demonstrated by the payment of contributions or as a matter of general social policy. Food inflation is defined as the year-on-year change in the food component of a country's Consumer Price Index. The share of income held by the bottom 20% of the population comes from the World Bank's World Development Indicators (WDI). The food import dependency variable is computed as the ratio between the food import bill (FAO) and total exports (WDI).

Our final estimation sample comprises 142 countries across all continents and income groups and spans a period of eighteen years between 2001 and 2018. Countries with zero observations for the dependent variable or any of the independent variables were dropped from the sample.

TABLE 1: Descriptive statistics for outcome variables

	PoU_0	$\Delta ln(PoU)$	CER_0	$\Delta ln(CER)$	$PROT_0$	$\Delta ln(PROT)$
LIC	0.33	-0.03	0.66	-0.003	9.3	0.021
LMC	0.19	-0.022	0.59	0	19.1	0.017
UMC	0.09	-0.022	0.47	-0.005	30.8	0.011
HIC	0.042	-0.007	0.34	-0.001	56.1	0.002
East Asia & Pacif.	0.13	-0.02	0.50	-0.008	34.2	0.012
Europe & C. Asi	0.05	-0.015	0.38	-0.004	50.4	0.008
L. America & Carib.	0.14	-0.022	0.42	0	32.1	0.009
MEAN	0.07	-0.014	0.49	-0.001	32.8	0.008
North America	0.02	0	0.27	-0.001	66.2	-0.005
South Asia	0.24	-0.036	0.67	-0.004	12.1	0.017
SSA	0.22	-0.014	0.61	0.002	15.4	0.016
Total	0.12	-0.017	0.47	-0.002	34.5	0.01

[a] Note: Sample averages by income level and geographical area of the initial value of the prevalence of undernourishment (PoU_0), the share of energy from cereals, roots and tubers (CER_0) and average supply of animal protein in gr/cap/day ($PROT_0$). Δln(PoU), Δln(CER), Δln(PROT) stand for the growth rates of the PoU, cereal share and protein supply. We use the World Bank definition of income groups.

Table 1 reports descriptive statistics for the outcome variables. We show results for the original variables at the beginning of the observation period as well as for the transformed variables in the form they are used in the analysis. The first column shows the average prevalence of undernourished in 2001, the first year available in our sample, by income group and geographic area. The share of undernourished is the highest in low income

TABLE 2: Descriptive statistics for control variables

	GDP_0	$\Delta ln(GDP)$	SP_0	$\Delta ln(SP)$	FI_0	ΔFI
LIC	1.6	0.022	27	0.064	0.07	-0.002
LMC	3.9	0.029	166	0.049	0.06	-0.002
UMC	9.8	0.027	968	0.035	0.10	-0.003
HIC	36.8	0.016	4495	0.019	0.04	-0.001
East Asia & Pacif.	16.5	0.03	814	0.048	0.04	-0.001
Europe & C. Asi	26.6	0.027	4023	0.034	0.08	-0.003
L. America & Carib.	9.8	0.018	1044	0.024	0.07	-0.001
MEAN	25.4	0.01	2155	0.017	0.04	0
North America	43.9	0.013	4712	0.014	0.04	-0.001
South Asia	3.1	0.038	131	0.102	0.06	-0.001
SSA	4.2	0.021	300	0.034	0.07	-0.002
Total	16.8	0.023	1916	0.035	0.07	-0.002

[a] Note: Sample averages by income level and geographical area of the initial value of the GDP per capita in thousands of I$ (GDP_0) and social protection expenditure per capita in I$ (SP_0) and food inflation FI_0. Δln(PoU), Δln(GDP), Δln(SP) stand for the growth rates of the PoU, income and social protection. ΔFI stands for the absolute changes of food inflation. We use the World Bank definition of income groups.

countries (LIC), where one every three people was undernourished in 2001, and it declines with higher stages of economic development, falling to 4.2% in high income countries (HIC). As to the geographic distribution of the undernourished, the highest concentrations are in South Asia and Sub-Saharan Africa, where a quarter of the population was undernourished. The second column shows the average over time and over countries of the year on year change of the PoU. We highlight that LICs, which started out with the highest levels of undernourishment, also show the highest reductions, while average change is the slowest in the HICs. This lends support to the convergence hypothesis of a higher catching up speed of the most disadvantaged countries. The share of energy from staple foods (column 3) is decreasing in the level of development, while the consumption of protein from animal products (column 5) increases with GDP per capita with ever smaller rates (last column).

Table 2 shows the average annual growth of GDP per capita and of social protection expenditure per capita over the sample period (columns 1 and 3, respectively). We notice that an increasing share of countries' resources have been allocated to social protection. This trend is driven mostly by developing countries that had extremely low coverage in the early 2000s and saw a proliferation of social protection programs in the 2010s (Lowder

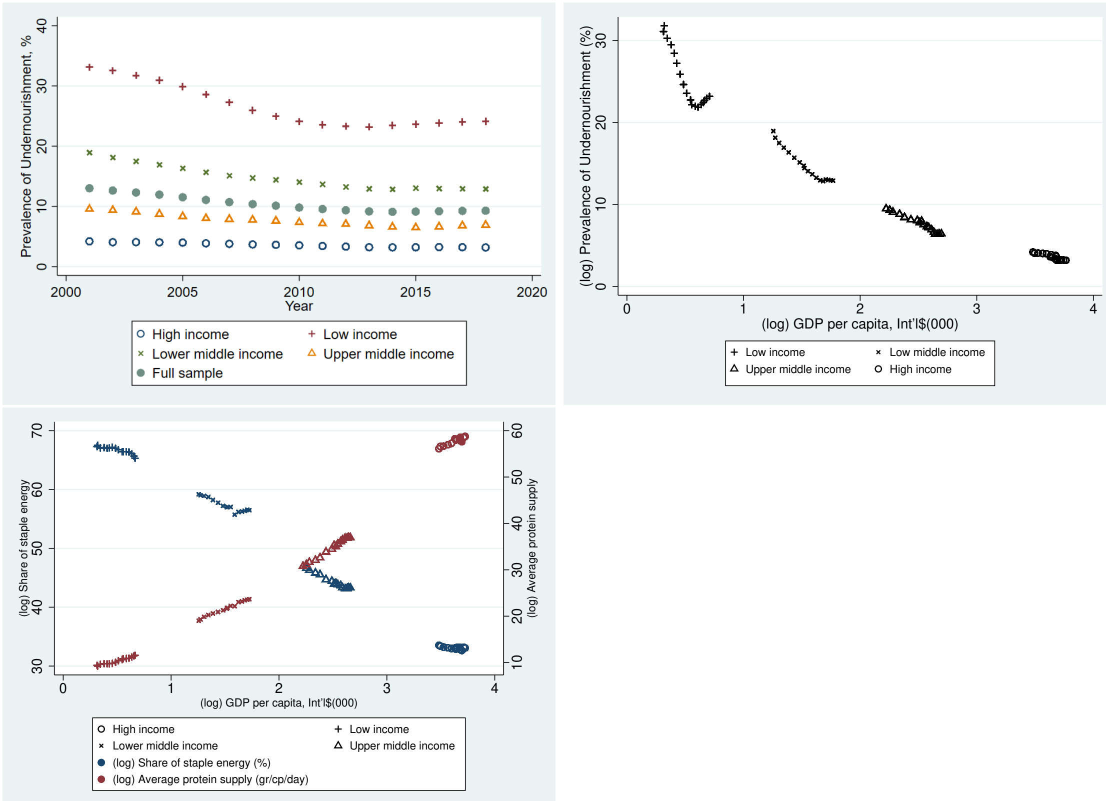

FIGURE 1: (A) Evolution of PoU over time and by income group (B) Relationship between (log) undernourishment and (log) GDP per capita by income group (C) Relationship between (log) diet composition and (log) GDP per capita by income group.

at al., 2017). In fact, social protection expenditure outgrew GDP by three times in LICs and by two times in LMCs, while it grew at the same pace as GDP in HICs. The level of food inflation in developing countries at the beginning of the observation period was almost double the one observed in the rich world (column 5), providing suggestive evidence of a positive association between food prices and undernourishment. The last column shows a secular reduction towards lower food inflation in the two decades covered by the study.

The top left graph of figure 1 shows the evolution of the PoU in the sample period by income group. Low income countries exhibit the fastest reduction in undernourishment until 2013, but the gap with the rest of the world remains large and has been widening in the last years due to a slight uptick in undernourishment in the LIC group, which has been attributed to increased occurrences of civil conflicts and weather anomalies, that in turn disrupt economic activities and distort prices (FAO, 2009). The undernourishment gap is large also between the low-middle- and upper-middle-income groups and stops narrowing after 2013. At the end of the observation period, undernourishment in low- *vis-à-vis* high-income countries diverge by a factor of ten, suggesting that the road to convergence towards some equilibrium level is still long.

The top right graph of figure 1 offers a descriptive view of the relationship between (log) undernourishment and (log) real GDP per capita. Undernourishment decreases with GDP per capita, but it also becomes less responsive to income growth as countries become richer, which is shown by the curves getting flatter. The bottom left graph of figure 1 shows how (log) average diet composition varies with (log) income. We notice that as countries develop, they tend to substitute cereals and staple foods with animal products. While animal protein demand increases with a similar rate across income levels, staple consumption shows a more convoluted behaviour. We can notice some resemblance to an inverse S-shaped curve, as the share of energy from staples is almost flat at very low levels of income, starts declining rapidly as countries develop and plateaus for HICs. These figures suggests inverse associations with income for PoU and energy from staple foods and a direct one for animal products, although they show only the "between" part of the co-variation, since we take averages over all countries for a given year. Depending on how much weight a given panel data estimator gives to the "within" and "between" variation, results may change substantially. In the next section, we study in a rigorous regression framework these relationships, while controlling also for the effect of other determinants and addressing issues of possible endogeneity that can confound the relationships, in an attempt to establish a clear direction of causality.

5 Empirical Strategy

We are interested in estimating the relationship between food insecurity at the national level and its macroeconomic determinants, namely, real GDP per capita, the general level of food prices, and indicators of relevant policy measures like social protection expenditure. More formally, we can cast this relationship through a linear model:

$$y_{it} = \alpha + (\beta_0 + \gamma_i)t + \beta_1 X_{it} + u_i + \epsilon_{it} \tag{1}$$

where y_{it} represents our food insecurity and dietary measures for country i at time t, namely, the log of the prevalence of undernourished, the log of the share of dietary energy from cereals, roots and tubers, and log of the animal protein supply. On the right-hand side of equation (1) we include global and country time effects to control for phenomena that impact all countries in a similar fashion (t) while the matrix X_{it} includes our three main macro drivers, i.e., log GDP per capita, food inflation, and a redistribution measure given by log of per capita social protection expenditure. The composite error term includes country-specific time-invariant unobserved heterogeneity (u_i) to capture geographical, historical or slow-changing institutional factors and a mean zero idiosyncratic shock (ϵ_{it}).

We adopt a first difference instrumental variables (FD-IV) estimation approach, to address concerns over omitted variables and reverse causality—which could lead to biased estimates from endogenous co-variation between the composite error term and the controls. In our setting, time-invariant unobservables (u_i) like historical background and geographical position may be correlated not only with food insecurity but also with GDP and the rest of the right-hand side variables, thus potentially confounding the relationship. Taking the first difference of equation 1 eliminates u_i and excludes the possibility of bias from correlation of X_{it} with time-invariant omitted variables. Moreover, taking first differences allows to cast the relationship in terms of rates of change, since our interest lies more on the short-term variations of food insecurity along the phases of the business cycle. [4] We obtain the following equation:

$$\Delta y_{it} = \beta_0 + \theta y_{i0} + \beta_1 \Delta X_{it} + \Delta\epsilon_{it} \tag{2}$$

Where variables and coefficients have the same meaning as before while we assume that $\gamma_i = \theta y_{i0}$ to capture a time-invariant regressor that controls for initial conditions allowing us to investigate whether there is convergence among countries towards some "equilibrium level" of food insecurity. Countries that start out from higher levels of food insecurity should exhibit a faster pace of catching up (Marelli et al, 2019).

To the extent that endogeneity stems only from omitted variables and these can be accurately represented by u_i, applying least squares to equation 2 (i.e. simple first differences - FD) would still yield unbiased results without the need to resort to instrumental variables. However, endogeneity may also comes from correlation of the controls with the idiosyncratic shock even after having netted out u_i. This situation is often pervasive in a macro setting and potentially more problematic. In fact, it could be the case that a given year's shock to food security may feed back to next year's social protection spending with governments reacting quickly to distress situations by scaling up social transfer schemes. Further, after a shock to food security, vulnerable households may switch to cheaper food items driving their prices up, which may trigger further reactions by policy makers that ultimately lead to endogenous changes in the future growth rate too. These scenarios invalidate the strict exogeneity assumption, which requires the error term to be uncorrelated with past, current and future values of the covariates ($E[\Delta\epsilon_{it}|\Delta X_{is}] = 0$ for $s = 1, 2..t..T$). The resulting least squares estimates of equation 2 would be downward biased. A more realistic assumption that fits our setting is weak exogeneity, i.e., the error in each time period is assumed to be uncorrelated with past and present values of the explanatory variables but can be correlated with future values of the explanatory variables ($E[\Delta\epsilon_{it}|\Delta X_{is}] = 0 \, \forall s \leq t$). This implies that no past values of the explanatory variables affect current values of the response variable after controlling for current ΔX_{it}. This opens up the possibility of using lagged values of the endogenous variables as instruments. The possibility of using internal instruments is a big advantage, considering the difficulty of coming up with enough credible instruments from outside the system. The first difference transformation is preferable to other within group transformations (e.g. demeaning), since it is compatible with a weak exogeneity assumption. If demeaning was applied to equation 1, the transformed error term would be a function of its own past, present and future values, which requires strong exogeneity

[4]This has also the benefit of removing possible unit roots in the variables, making sure that we are using stationary variables on both sides of the equation so that to avoid spurious findings.

for consistent estimation and precludes the possibility that lagged covariates can serve as instruments.

We follow previous literature and use one and two years lags of the right-hand side variables in levels as instruments $\mathbf{Z}^1 = \{X_{it-1}, X_{it-2}\}$ (Bittencourt, 2010).[5] Being predetermined, X_{it-1} and X_{it-2} are not affected by the current time error and affect current values of undernourishment only through their effect on current ΔX_{it}. This allows to obtain consistent estimates even if reverse causality is present, provided the lagged variables can be safely excluded from the estimating equation i.e., $E[\Delta\epsilon_{it}|\mathbf{Z}^1, \gamma_i] = 0$ (Anderson and Hsiao 1981; Reed, 2015). In the results section, we provide evidence of the plausibility of the weak exogeneity assumption underpinning the instrumental variable strategy.

Finally, we investigate the heterogeneity of the short-term effects of growth along selected structural characteristics of the economy by interacting the variables in changes with the level of four variables: GDP per capita that captures a country's stage of economic development; the income share held by the bottom 20% and the level of social protection expenditure, both of which reflect economic inclusiveness and inequality; the food import dependency ratio measured as the share of the food import bill on total export revenues, which proxies a countries vulnerability to changes in global food commodities markets and external economic conditions. A model with linear interactions is a standard way to explore effect heterogeneity (Abrevaya et al., 2015).

$$\Delta y_{it} = \beta_0 + \theta y_{i0} + \beta_1 \Delta X_{it} + \beta_2 W_{it} + \beta_3 \Delta X_{it} W_{it} + \Delta\epsilon_{it} \tag{3}$$

where ΔX_{it} includes only GDP growth this time and where W_{it} represents a set of level variables. Equation (3) is estimated under the same identifying assumptions and with the same approach as equation (2), that is, taking first differences to handle the presence of unobserved heterogeneity combined with instrumental variables to address endogeneity from reverse causality. The inclusion of level variables poses a bigger threat to the strict exogeneity assumption, since in the long run a country's level of income, for instance, is both a determinant of undernourishment and diet composition and is in turn affected by these variables (Fogel, 2014). In this case, we resort to a set of external instruments for the level variables W_{it}, which is sourced from the literature and is defined as $\mathbf{Z}^2 = \{$contemporaneous and one year lag of the average seasonal temperature levels, average monthly rainfall deviations, aggregate age dependency ratio in the population$\}$. These are added to the instruments for ΔX_{it} and their interactions are also used as instruments in estimation so that the final set of instruments for equation 3 is $\mathbf{Z} = \{\mathbf{Z}^1, \mathbf{Z}^2, \mathbf{Z}^1 \times \mathbf{Z}^2\}$.

[5] We treat y_0 as a potentially endogenous variables like the rest of the variables in X_{it}. However, being time-invariant, y_0 cannot be used to form instruments by lagging or taking first differences.

6 Results

Table 3 shows the estimated coefficients for our main equation (2), where changes in the (log) share of undernourished are regressed on economic growth, changes in food inflation, on (log) per capita social protection expenditure and initial conditions of undernourishment. Column (1) shows the simple first differences (FD) estimates, while column (2) has the results for the first difference instrumental variables (FD-IV) estimator.

The FD estimator yields an income elasticity of undernourishment of around 0.3 percent. The effect of food inflation is 0.03 percent but is estimated imprecisely. These results are similar to those of Soriano and Garrido (2016) and Heady (2013). The latter finds that GDP growth reduces by 0.2 percent a measure of subjective food insecurity (FIES), while food inflation was found to have no significant impacts. We attribute the difference in results to the different approaches towards endogeneity bias in the two studies. Per capita social protection expenditure has a significant although less steep gradient compared to the income and food prices at 0.01 percent.

However, ignoring endogeneity of macro variables on the grounds of scarcity of convincing instruments is bound to lead to biased estimates. Allowing for the possibility that ΔX_{it} is correlated with the idiosyncratic term is important, since the strict exogeneity assumption that guarantees the unbiasedness of the FD estimator is unlikely to be valid in a macro setting, especially when some of the independent variables are policy instruments, like social protection in our case. In fact, in case of unprecedented shocks to food security (such as a pandemic or sustained increase in food prices as in 2008-12), that trigger an expansion of safety nets (*feed back* effect), the errors today are correlated with next period's values of social protection spending, thus violating strict exogeneity. Hence, we adopt a general approach to addressing potential endogeneity bias based on instrumental variables.

Before commenting the FD-IV coefficient estimates, we show through standard diagnostic tests for the first and second stage that our instruments are both strong predictors of the endogenous variables and uncorrelated with the error term. Proving the relevance of the instruments is important because when instruments are only weakly correlated with regressor, even the slightest correlation between the instrument and the idiosyncratic error in 2 might induce a large inconsistency in the second stage estimates. The last column of table 3 shows for each potentially endogenous regressor the F-statistics and the corresponding p values for the test that the coefficients of the exclusion restrictions are jointly zero in the first stage. The null hypothesis of joint insignificance of the exclusion restrictions is always rejected and the F statistics are generally above the Stock and Yogo threshold of 10. Having many instruments, we provide evidence of their exogeneity through a Hansen test of over-identifying restrictions. In our case, the weak exogeneity assumption implies that past values of GDP, food inflation and social protection affect current undernourishment changes only through their influence on current growth, food inflation and social protection expenditure changes. Like all assumptions, weak exogeneity does not necessarily always hold, which is why we provide evidence on its plausibility in our data. Test statistics and the corresponding p values are reported in the last line of table 3. We cannot reject the null hypothesis (p-value ≈ 0.46) of instrument validity. This guarantees the consistency of the IV estimates of the effects of income, food inflation and social protection on food insecurity. Finally, a Hausman test of endogeneity for ΔX based on the comparison of the FD *vis-à-vis* FD-IV sets of estimates did not provide sufficient evidence in favor of the null hypothesis that the potentially endogenous regressors can actually be treated as exogenous (p value = 0). Considering this and the reliability of the instruments, our preferred set of estimates is based on the instrumental variable approach.

Instrumental variable estimates have the same signs as the least squares ones, but the magnitudes of all effects increase by a factor of 2 to 3. Hence, a 1 percentage point increase in economic growth leads to an approximately 0.75 percent reduction in the share of undernourished. The inflation elasticity of undernourishment is smaller than the income one, as for every 1 percentage point increase in food inflation, the share of undernourished increases by around 0.12 percent. We are unable to place this estimate in a range of plausible magnitudes since we are unaware of previous work on the effects of food inflation on the prevalence of undernourishment. Other studies document a deterioration of food insecurity as food prices increase, although they use subjective perception-based measures of food insecurity and find considerably larger effects - from 1% to 5% - (Martin-Prevel et al., 2012; Nord et al. 2014)

Social transfers, being in part directly targeted to the share of population most vulnerable to food insecurity, have a significant direct impact in curbing undernourishment. Every 1 percent increase in per capita social protection expenditure reduces undernourishment by 0.03 percent in the FD-IV approach. When it comes to gauging the relative strength of the effects on undernourishment of its three determinants, comparing elasticities may distort the picture, because a 1 percent change in x means different things depending on the scale of the distribution of x. In fact, the standard deviation of food inflation and of social protection expenditure are 1.5 and 8 times larger than the standard deviation of income. To adjust the elasticities for the different spread of the distribution of the regressor they refer to, we multiply the coefficient of food inflation by 1.5 and that of social protection by 8. Hence, a typical change in food inflation is associated with an increase in undernourishment of 0.175 percent. Further, a typical change in social protection expenditure has a similar strength as food inflation, leading to a reduction in undernourishment of 0.237 percent. After the adjustment, economic growth is confirmed as the biggest driver of improvements in undernourishment. The effect of social transfers expansions is four time smaller than that of income, which makes them just enough to offset the effects of rising prices.

Finally, we find that countries that start out with higher levels of undernourishment at the beginning of our observation period, exhibit a higher reduction rate but the catching-up is slow in absence of other improvements as shown by the FD estimate. The speed of convergence is about 0.4 percentage point per year for a typical low-income country that starts with a 20 percent share of population undernourished. The catch-up effect disappears in the FD-IV approach, so we conclude that the race to close the undernourishment gap between the developing and the developed world has currently come to a halt.

TABLE 3: Estimation results of main equation: PoU

	FD	FD-IV	First stage
y_0	-0.013***	-0.004	15.55
	(0.001)	(0.003)	(0.000)
Δ ln GDP pc	-0.310***	-0.748***	14.02
	(0.061)	(0.172)	(0.000)
Δ Food inflation	0.032	0.116*	57.78
	(0.024)	(0.064)	(0.000)
Δ ln Social transfers	-0.010***	-0.030**	5.28
	(0.003)	(0.013)	(0.000)
_cons	-0.043***	-0.007	
	(0.004)	(0.012)	
N	2232	2083	
Overidentification test		1.56	
(P value)		(0.46)	

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last column shows the F test statistics from the first stage of each regressor and the corresponding p value.

Moving to the analysis of the qualitative aspects of food insecurity, table 4 has the effects of the same set of regressors as before on our two diet composition variables. The first two columns report the FD estimates for the dietary energy share from starchy staples and the average animal protein supply. Only income plays a role in dietary habits with a 1 percent increase in GDP leading to a 0.07 percent reduction in the consumption of cereals, roots and tubers and a 3.3 times higher increase in the consumption of animal products (+0.24 percent). Coefficients for food inflation and social transfers are indistinguishable from zero. The coefficient on the initial conditions are negative and significant but small in size, indicating very slow convergence of diet patterns across countries.

The middle columns of table 4 report FD-IV results. Coefficient estimates for income, food inflation and social protection are larger than the corresponding FD estimates. A 1 percent increase in income leads to a 0.23 percent reduction in the staple share of dietary energy and to a 0.82 percent increase in absolute value of proteins from meat and fish consumption. Salois et al. (2012) find a GDP elasticity of average protein consumption that is close to our FD estimate. We interpret this as an indication of the convenience of our choice to explicitly address endogeneity concerns, since Salois et al. (2012) warn that the main caveat of the study is the lack of a proper strategy to address possible endogeneity bias.

TABLE 4: Estimation results of main equation: diet composition

	FD		FD-IV		First stages	
	CER	PROT	CER	PROT		
y_0	-0.008***	-0.010***	0.006	-0.002	48.48	96.75
	(0.002)	(0.001)	(0.004)	(0.003)	(0.000)	(0.000)
Δ ln GDP pc	-0.073***	0.239***	-0.227***	0.812***	18.43	18.43
	(0.020)	(0.035)	(0.070)	(0.249)	(0.000)	(0.000)
Δ Food inflation	0.001	-0.030	0.030	-0.173***	58.3	58.3
	(0.007)	(0.019)	(0.023)	(0.045)	(0.000)	(0.000)
Δ ln Social transfers	0.002	-0.003	-0.010	-0.002	4.6	4.6
	(0.002)	(0.003)	(0.010)	(0.019)	(0.000)	(0.000)
_cons	-0.007***	0.038***	0.008**	-0.006		
	(0.002)	(0.005)	(0.003)	(0.016)		
N	2139	2139	1975	1975		
Overidentification test			5.12	1.56		
(P value)			(0.08)	(0.46)		

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last two columns show the F test statistics from the first stage of each regressor and its p value.

We note that the integration of animal products into diet occurs at a higher pace than the phasing out of cereals, roots and tubers, which are staples for almost all societies, regardless of the level of development. As a result, their weight in diet reduces slowly, as higher income allows access to more expensive sources of calories and poor countries move towards richer and more balanced diets. Changing the prospective from a boom to a recession, reactivity of diet composition to income changes means that households adjust their food basket moving to cheaper sources of calories and reducing the consumption of expensive items like meat and fish. Further, diet composition, like the PoU, is more responsive to changes in real income than in food inflation. In fact, relative to the simple FD estimates, here we notice that a rise in food prices does not lead to an increase in the consumption of cereals but it does reduce meat and fish consumption. Given their nature of necessities, demand for staples like cereals, roots and tubers should be less price-responsive than the demand for higher-value foods. The reactivity of dietary habits to the business cycle, shows that to avoid falling below the undernourishment threshold, people will use diet composition as a buffer to absorb price and income shocks. However, downward diet adjustments are perceived as a descent into poverty and may act as the prelude to social discontent and possibly unrest. In the FD-IV approach, the effect of initial conditions becomes insignificant, indicating that there has been no convergence in dietary pattern across patterns. Regardless of the estimation approach, social transfers do not seem to affect diet composition, although micro level studies show consistently that access to social protection programs increases dietary diversity and protein consumption (Hidrobo et al., 2014).

The last two columns show the first stage F statistics for the equations of the energy share from staples and animal protein supply. They are identical, except for initial conditions, since for both outcome variables the same right hand side variables are included and the same instruments are used. All three first stages show that our instruments are strongly correlated with the endogenous variables. Moreover, the test of overidentifying restrictions supports instrument validity. Hence, we prefer the FD-IV estimates to the simple FD ones as they correct for the possible presence of endogeneity bias from reverse causality between food insecurity and our controls. In fact, a Hausman test of endogeneity based on the comparison of the FD *vis a vis* FD-IV sets of estimates confirms the endogeneity of our regressors.

6.1 Heterogeneity of effects

The relationship between food insecurity and the GDP cycle can change over time as countries become richer or slowly adjust their structural characteristics. To see how the effects of growth vary with a country's characteristics, we use the total effect of growth from equation 3, $\beta_3(W) = \beta_1 + \beta_3 W$. This is plotted as a function of each element of W in figure 2. To save on space we show only the FD-IV estimates, since they provide higher guarantees of consistency [6]. The estimates underpinning figure 2 are shown in Table A1 in appendix. First stage F tests reject the null hypothesis that the coefficients of the excluded instruments are jointly zero for all regressors. The Hansen test of overidentifying restrictions fails to reject the null hypothesis of exogeneity. Hence, we are confident about the overall consistency of the FD-IV estimates.

The top left graph of figure 2 shows that undernourishment reacts to business cycle fluctuations for a broad range of GDP values (I$ 30 thousand). Economic growth plays an important role in reducing hunger, especially at the early stages of development, but becomes less effective as countries grow richer and undernourishment plunges to low levels. This implies that the long term relationship between the levels of undernourishment and income is non-linear. As economic development progresses, undernourishment initially falls at a fast pace but after a certain level of income the process slows down as countries reach minimum levels of hunger. This confirms the conclusions drawn from the descriptive analysis of figure 1. For LICs that are still at the early stages of development the steeper curve implies that undernourishment declines rapidly as income grows. For the HICs the curve is considerably less steep as income increases lead to smaller reductions in hunger. The higher income elasticity of hunger in middle- and low-income countries relates also to a bigger share of population that is closer to the undernourishment threshold and that is shifted above or below the threshold as income oscillates.

[6] FD estimates are available upon request from the authors

The top right graph shows that growth is more effective in reducing hunger in countries with more inclusive economic systems in which the bottom 20 percent of society holds larger shares of national income. The gradient is very steep, as growth effectiveness in curbing undernourishment is 25 percent higher in a country where the bottom 20 percent of society holds 15 percent of national income relative to a country where the poor hold only 5 percent of income. Another way to see this relationship is through the lens of inequality. Higher inequality reduces the elasticity of undernourishment to GDP growth, and the flip side of the story suggests that the same process that during good times makes growth more inclusive reverts when growth declines or the economy contracts. Further, growth is a substitute to social protection in reducing hunger, as growth is an important hunger-reducing mechanism when expenditures on social protection (as % of GDP) are small, but becomes irrelevant when social protection expenditures instead reach considerable levels. This may be explained in terms of the counter-cyclical nature of social protection spending. In fact, unemployment benefits as well as means-tested social assistance programs (cash and food transfers) expand rapidly during recessions and retract as the business cycle reverts and economies recover (Bitler et al., 2020). Finally, economic growth works better when combined with low to moderate food import dependency ratios. As countries start meeting domestic demand for food with an ever-increasing share of imports, growth loses its effectiveness. The higher exposure to the vagaries of international food commodities markets may reduce the responsiveness of undernourishment to the domestic business cycle.

We investigate also how the effect of growth on diet composition varies with the level of development and the overall level of inclusiveness of the economy. Results are represented graphically in figure 3, while the underlying FD-IV estimates of equation 3 are reported in table A2 in the appendix. First stage diagnostic tests show that our instruments are strong predictors of the endogenous variables in both equations, but based on the test of overidentifying restrictions, we are highly confident that the instruments are exogenous only for animal protein (p value 0.25). For cereal consumption the Hansen test provides only weak evidence in favor of instrument exogeneity. Hence, consistency is not fully guaranteed and the corresponding results should be interpreted with this caveat in mind. The top left graph in 3 shows that income growth leads to a reduction in the consumption of cereals, tubers and roots at the early stages of development, probably because people in poor countries tend to over-consume these cheaper source of calories. The move away from cereals stops earlier in the development process (I$ 15000) than figure 1 would seem to suggest (top left graph). Moreover, our results do not align entirely with the S-shape hypothesis of diet quality, as this would imply an income elasticity of zero at very low levels of GDP per capita. Consumption of animal-based food on the other hand (top right graph) responds positively to growth up until countries are well ahead in their development process. Growth in demand for animal products outlasts the reduction in demand for staples. In fact, meat and fish saturation of diets occurs at a level of GDP per capita of around I$ 50000, way above the level of income at which staple consumption stops decreasing. The bottom two

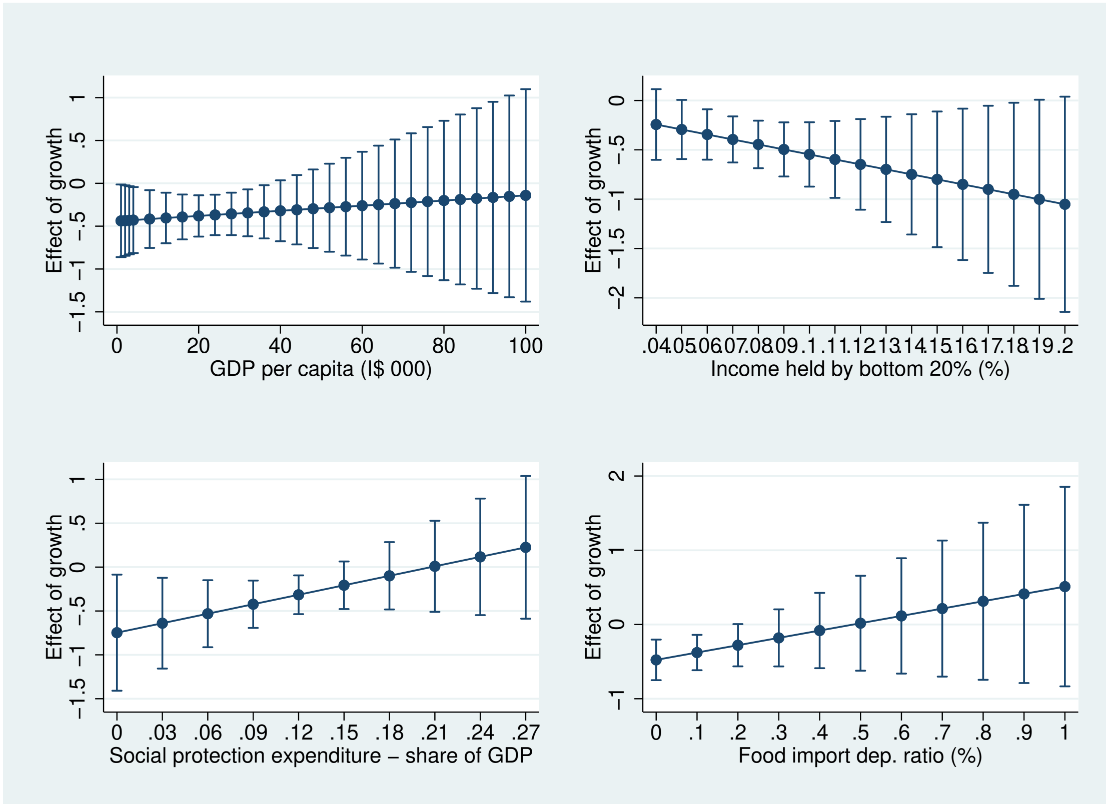

FIGURE 2: Growth effects variation.

graphs show how the growth elasticity of diet composition varies with the share of income held by the bottom 20 percent of society. Inclusiveness does not affect the relationship between growth and consumption of cereals, roots and tubers. This may be due to the fact that cereals consumption is more uniformly distributed within countries due to its pivotal nutritional role. On the other hand, inequality matters for the more expensive foods, like meat. The lower the inequality in the economy, the stronger the effect on animal protein consumption of a given change in average income.

Overall, we notice that both aspects of food insecurity are reactive to the business cycle, which implies that during recessions there may be temporary spikes in undernourishment and households will use diet reallocation as a coping mechanism to prevent descent into caloric insufficiency. The link between food insecurity and the business cycle is stronger at the early stage of development. In poor countries, on the one hand there are more people living on the edge of undernourishment, and on the other hand diets are tilted towards staples and the distance from a balanced diet is larger. Both circumstances lead to higher reactivity of undernourishment and diet composition for a given change in purchasing power.

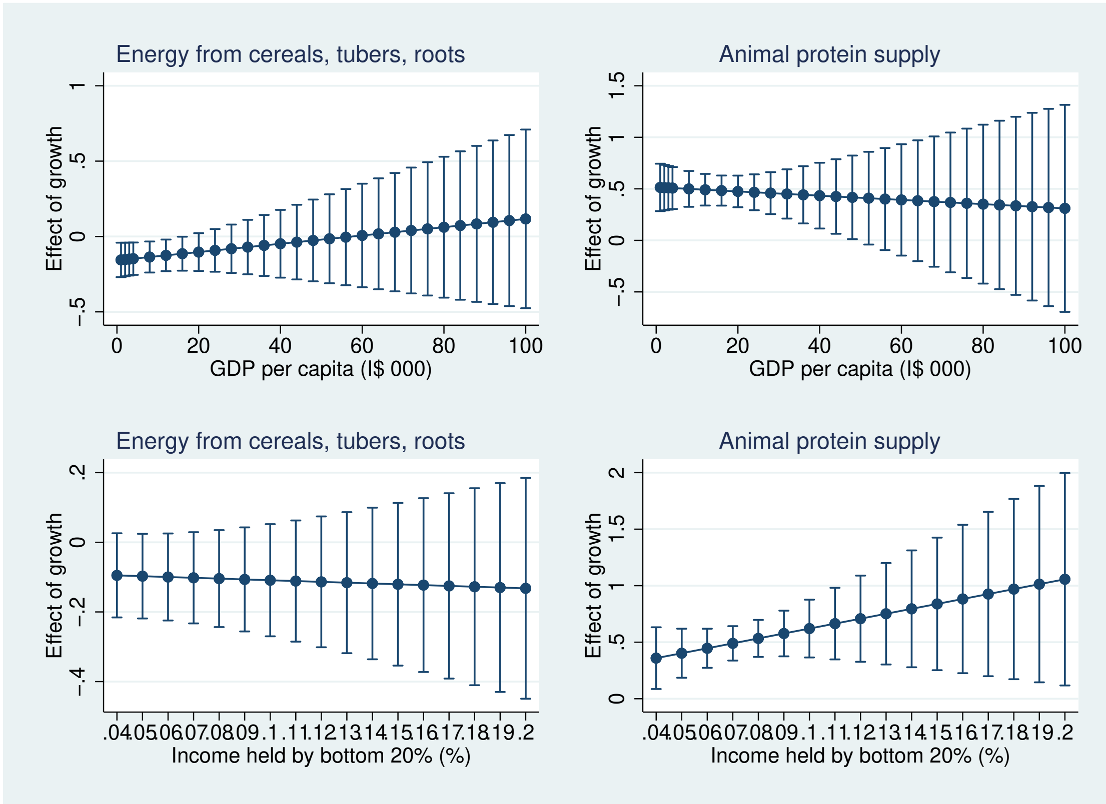

FIGURE 3: Growth effects variation for diet composition.

6.2 Sensitivity analysis

We conduct several robustness checks concerning the reliability of our instruments, the stability over time of the parameters, the sensitivity of the estimates to changes in the sample, in the specification of the regressors and the functional form assumption in our main equation. To save on space, results of the robustness checks are provided only for the analysis of PoU.

First, we check the sensitivity of our estimates to changes in the instruments set. Having assumed a weaker form of exogeneity for our regressors allows to use as instruments either lagged levels or differences of the endogenous variables themselves. Hence, we re-estimate the main equation, first by using a combination of first lag levels and first lag differences as instruments $\mathbf{Z}^1 = \{\Delta X_{it-1}, X_{it-1}\}$. Alternatively, we restrict the instruments' set to the first lag of the differenced endogenous variables $\mathbf{Z}^1 = \{\Delta X_{it-1}\}$. In this case, we are treating y_0 as exogenous and the model is just identified. The first two columns of table 6 show results for the overidentified and the just identified models, respectively. In both models the first stage shows that instruments have generally a strong correlation with the endogenous regressors and for the overidentified model the Hansen test shows that they are uncorrelated with the error term in equation 2. In the overidentified model, coefficient estimates for all regressors are very close to the benchmark estimates in column 2 of table 3. This is also true for the just identified model, except for the food inflation coefficient which is twice as large as the benchmark estimate. Clearly, estimates in the overidentified model are more reliable, since they come from a set of instruments that have passed both tests of validity. However, the overall picture remains substantially unchanged even with these alternative sets of instruments.

TABLE 5: Estimates with alternative set of instruments

	FD-IV		First stages	
y_0	-0.004	-0.010***	90.51	
	(0.003)	(0.002)	(0.000)	
Δ ln GDP pc	-0.748***	-0.776***	15.51	6.98
	(0.172)	(0.187)	(0.000)	(0.000)
Δ Food inflation	0.116*	0.234**	46.02	32.43
	(0.064)	(0.100)	(0.000)	(0.000)
Δ ln Social transfers	-0.030**	-0.030**	3.75	6.11
	(0.013)	(0.013)	(0.000)	(0.000)
_cons	-0.007	-0.022**		
	(0.012)	(0.010)		
N	2083	2083		
Overidentification test	1.56			
(P value)	(0.46)			

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The first two columns show FD-IV estimates with two alternative sets of instruments. The last two columns show the F test statistics from the first stage of each regressor and its p value.

Second, we explore the hypothesis of a structural break in the prevalence of undernourished that may give rise to two different regimes in its relationship with the covariates (Lockwood and Migali, 2009). From the visual inspection of figure 1, the PoU plateaus after 2013. We implement a Chow-like test by including a time dummy equal to one for years after 2013 and its interactions with income growth, food inflation changes and social protection expenditure growth.[7] Impossibility to reject the null hypothesis that the coefficients of these interactions and the time dummy are equal to zero would be evidence that the effect of our covariates do not vary over the two time periods, otherwise separate period-specific regressions would be appropriate. Coefficient estimates of the interaction terms shown in the first column of table 6 indicate that the effect of income, food prices and social transfers

[7]A Chow test assumes that the break date is known beforehand. To reduce the arbitrariness of the date choice, we repeated the test for 2012 and 2014 and obtained similar results.

do not change over the two periods. The set of instruments here is incremented with the interactions between the time dummies and the instruments of the benchmark specification. Diagnostic tests for the first and second stage show that the IV estimates are consistent. Coefficient estimates for X_{it} remain similar in magnitude to the benchmark results in table 3, although only the effect of income is estimated with sufficient precision.

TABLE 6: Test of parameter stability over time

	FD-IV	First stage
y_0	-0.003	56.31
	(0.005)	(0.000)
Δ ln GDP pc	-0.866**	17.01
	(0.436)	(0.000)
Δ Food inflation	0.055	34.55
	(0.126)	(0.000)
Δ ln Social transfers	-0.021	141.21
	(0.177)	(0.000)
D_1	0.638	10.02
	(0.478)	(0.000)
D_2	-0.081	7.58
	(0.213)	(0.000)
D_3	-0.006	60.46
	(0.177)	(0.000)
D_B	0.002	
	(0.010)	
_cons	-0.005	
	(0.019)	
N	1937	
Overidentification test	3.23	
(P value)	(0.66)	

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last column show the F test statistics from the first stage of each regressor and its p value. D_{2011} is a dummy that equals 1 for years after 2011.

Further, the slight uptick that can be observed in the last four years or so in our estimation sample is driven by LICs and seems concentrated in Sub-Saharan Africa. The main reason for the faltering of global hunger reduction process has been the surge in civil unrest episodes and local armed conflicts (FAO, 2018). There is a two way relationship between social unrest and economic factors, since changes in the economy (tax increase, currency devaluation etc) may contribute to social unrest which can further lead to important disruptions with stern economic consequences that further fuel the spiral of feedback effects. To shed light on this hypothesis, we control for the occurrence of social unrest. In a recent research Barret et al. (2020) have built two monthly indices of social unrest covering 130 countries based on media reports retrieved through a fixed set of sources and search terms (protests, riots, major demonstrations etc). The two indices are the share of articles about country i at month t that are about social unrest and the fraction of all articles at month t which are about unrest in country i. While the first indicator is easy to interpret it may suffer from excessive noise since many countries receive little coverage other than when there is social unrest, which artificially amplifies the index. The second index does not suffer from this drawback but has no comparability across countries. Hence, the authors use the two indices in a complementary way to define as social unrest an event at month t in country i if both indices reach extreme values (above 0.1 for the first index and top 2% for the second one).

Hence, we provide FD-IV estimates of equation 2 after controlling for the number of events in each country that in a given year constitute social unrest. The civil unrest indicator is included in changes like the rest of the time-varying regressors and is instrumented by its first and second lagged levels.[8] Diagnostic tests from first and second stage (table 7) indicate that the instruments are well correlated with the endogenous regressors and uncorrelated with the error term in the main equation. After controlling for social unrest, the effect of income growth is still statistically significant and slightly larger than in the benchmark specification. The effect of food inflation is similar in magnitude to the corresponding benchmark estimate but is imprecisely estimated, while the effect of social transfers disappears both statistically and substantially. Finally, one extra social unrest event in year t in a given country increases the share of undernourished by a very small amount on average. Hence we conclude that civil unrest events exert their influence on undernourishment indirectly through income and food price channels and have only a limited direct effect.

Third, we investigate the sensitivity of the estimates to slight variations in the sample composition by providing jackknife-like estimates of each parameter, whereby we systematically leave out one country from the sample. This procedure can identify the consequences of two types of events: the presence in the sample of countries with an unduly high influence on the average affect because of specific events related to that country, like episodes of hyperinflation; minor irregularities and outliers in the data, like the recent revision of the number of undernourished in China carried our by the FAO. One reassurance against all this comes from the country-specific effects in equation 1 that can net out some of these events. In fact, the top right graph in figure 4 shows that all estimates of the income elasticity of

[8]The range of the variable is [0,12]. We do not include it in logs to avoid having to deal with the issues of zeros, for which the logarithmic transform is not defined. In a specification in which we add 1 to the social unrest variable before taking logs, results do not change substantially.

TABLE 7: Sensitivity to controlling for unrest

	FD-IV	First stage
y_0	-0.007*	88.16
	(0.004)	(0.000)
Δ ln GDP pc	-0.894***	8.81
	(0.280)	(0.000)
Δ Food inflation	0.103	21.04
	(0.077)	(0.000)
Δ ln Social transfers	-0.001	3.9
	(0.055)	(0.000)
Δ Social unrest	0.009*	82.72
	(0.005)	(0.000)
_cons	-0.013	
	(0.018)	
N	1386	
Overidentification test	4.4	
(P value)	(0.22)	

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last column show the F test statistics from the first stage of each regressor and its p value. D_{2011} is a dummy that equals 1 for years after 2011.

undernourishment are close to the full sample value and even those that are further away are within the confidence interval of the full sample estimate. The same holds true for the other covariates, although jackknife effects for food inflation and initial conditions are more wobbly, indicating a higher cross-country variability of the corresponding relationships.

Finally, we ease the linearity assumption for our main equation and use the following semi-parametric fixed effects estimator.

$$\Delta y_{it} = \beta_0 + \theta y_{i0} + f(\Delta x_{it}) + \beta_1^- \Delta X_{it}^- + \Delta \epsilon_{it} \tag{4}$$

where the covariates set $\Delta X_{it} = \{\Delta x_{it}, \Delta X_{it}^-\}$ has been split so that the relationship between undernourishment and one of the covariates (Δx_{it}) can be modelled non-parametrically through the unknown function $f(.)$, while the rest of the covariates ($\Delta X_{it}^-\}$) are entered linearly. Since only one covariate at a time can be modeled non-parametrically, we estimate equation 4 for each of the three components of ΔX_{it} (Baltagi and Li (2002); Ai and Li, 2008). In the transformed equation, the function $f(.)$ is approximated by linear

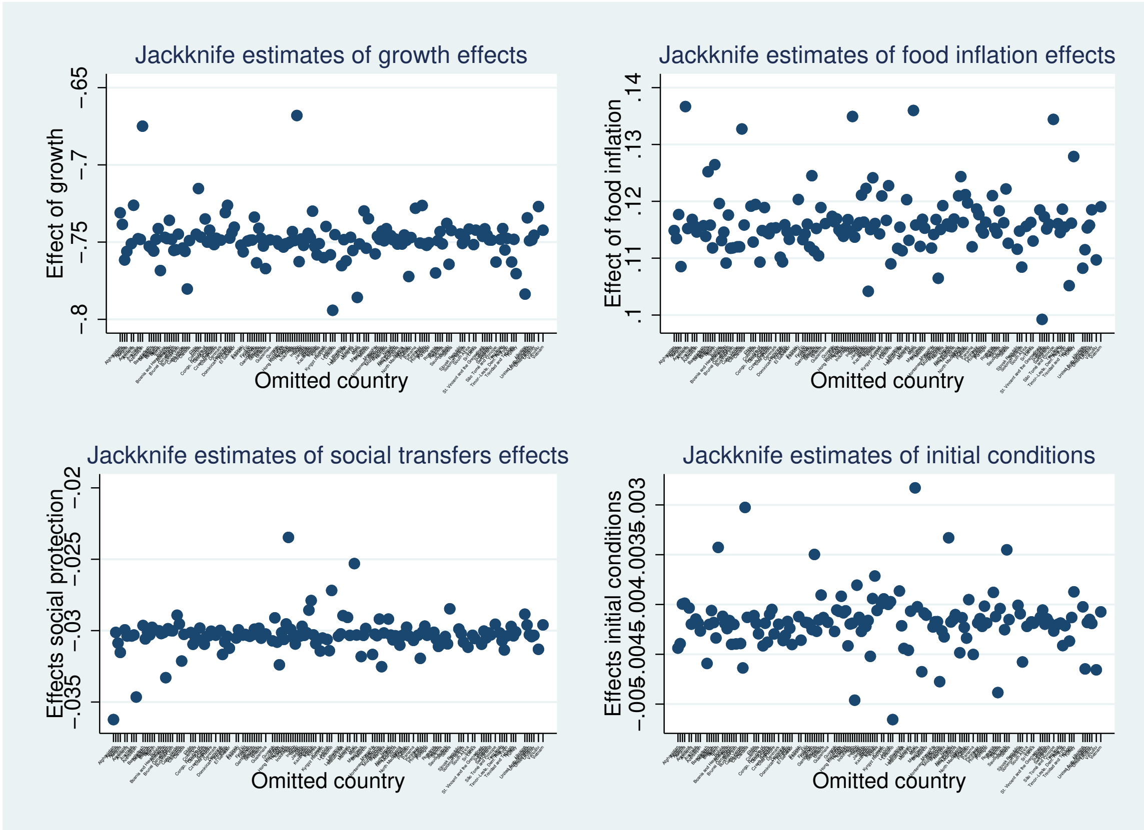

FIGURE 4: Jackknife effects

TABLE 8: Semi-parametric fixed effects estimates

	SP-FE
y_0	-0.000
	(0.000)
Δ ln GDP pc	-0.234***
	(0.031)
Δ Food inflation	0.015***
	(0.003)
Δ ln Social transfers	-0.009***
	(0.000)
N	2229

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

splines and estimation proceeds by OLS. This intermediate step serves to obtain the residuals which are used in the final step: $\hat{\epsilon_{it}} = \Delta y_{it} - \hat{\beta_0} - \hat{\theta} y_{i0} - \hat{\beta_1^-} \Delta X_{it}^- = f(\Delta x_{it}) + \eta_{it}$. Now the univariate function $f(.)$ can be fit through a local–constant Epanechnikov kernel regression.

The semi-parametric fixed effect (SP-FE) elasticity is given by the average derivative of $f(.)$ and is compared with the linear FE estimates of β_1 from equation 2. Here we ignore issues of endogeneity, since the aim is to check the sensitivity of the estimates to the linear form assumption, all other things being the same. Results in table 7 show that all effects are very close in magnitude to those in the first column of table 3. We take this as an indication that the linearity assumption is appropriate for our data.

7 Conclusion

Food security has repeatedly attracted the attention of governments and researches alike, not only because it relates to basic human needs but also because it can have important ramifications for social stability in the short run and for the economy in the long run. Most of the existing literature has concentrated on the relationship between individual and household characteristics and micro-level indicators of food security. The few existing studies with a macroeconomic angle have only examined the role of specific factors in isolation and in narrow single-country contexts. In our study, we use global data and take a more integrative approach that simultaneously considers multiple macroeconomic and policy variables which allows us to assess their relative importance, while addressing important issues like potential endogeneity that were previously ignored in the literature. Deepening our understanding of the macroeconomic determinants of national food security may help increase public understanding of its causes and inform possible policy measures that can contribute to its eradication.

More specifically, our study tries to answer the following questions: how do aggregate indicators of food insecurity react to business cycle oscillations i.e., GDP fluctuations; what is the role of domestic food inflation in exacerbating food insecurity; can boosting government spending on social protection serve as an effective measure to curb food insecurity, especially in moments of crisis; and, finally, is there convergence in food insecurity across countries, i.e., are countries moving together to some minimum level of food insecurity.

In our analysis, we find that economic growth is the most important driver of food insecurity, with a one percent increase in GDP per capita cutting the share of undernourished population by 0.75 percent. Our linear model implies symmetric effects of boom and bust episodes and, hence, an equal increase in undernourishment for a one percent contraction of the economy. However, given the global economy's natural tendency for growth in the medium to long run, this is likely to remain the major force reducing undernourishment. Although this may be true in general, we also found out that one attribute of growth, namely, inclusiveness, affects its ability to translate into improved food security. In other words, the growth elasticity of hunger is higher in economies where a higher share of national income goes to the bottom 20 percent of society. Where growth is accompanied with increased inequality a higher average income will not improve food security. Governments should promote inclusive growth by guaranteeing equal opportunities for everyone and those with disadvantaged backgrounds in particular, and by implementing redistribution policies to keep inequality in check.

Short-term oscillations of economic activity affect not just the average amount of calories people consume but also their average diet composition and diet quality, which also contributes to food security. In general, economic growth leads to a fast integration in diets of higher value food sources like protein and a somewhat slower reduction of staple sources like cereals and roots. This also implies that when the economy is hit by a recession, diet reallocation towards cheaper calories serves as a first buffer to prevent consumers' descent into undernourishment.

The influence of food inflation on food insecurity is considerably less strong than that of real income. A typical change in food inflation will raise the prevalence of undernourishment by 0.17 percent. This may be because we are controlling for real GDP, which is already netted of the rise in the general level of prices captured by the GDP deflator. This implies that if average nominal income keeps up with the general level of all prices including those of food and purchasing power is maintained, food prices alone will have a limited influence on undernourishment. However, history has proven that spiking food prices have a high potential for creating public discontent. For this and other reasons governments tend to pursue food price stability.

Generally, food prices do not respond to monetary factors, as they are determined by food market-specific real drivers, but general price stability becomes important for the elimination of undernourishment as it allows households to preserve their purchasing power and guarantee access to food. As for food price stability itself, previous research has shown that countries should use regional emergency food reserves as a guarantee against domestic food supply shocks (bad harvest in a given year) and rely on free international trade to navigate around global production shocks (Gouel, 2013). However, while trade will share the pain of a global shock across countries, adequate global reserves are the ultimate insurance against a true global shock. When, despite all the best efforts, food inflation does occur, it's usually the poorest who suffer more, since they spend a higher share of income on food. The use of countercyclical social protection in the form of scalable safety nets or unemployment benefits in moments of crises becomes crucial to safeguard the ability of the most vulnerable to purchase food in the face of rising food prices and prevent their descent into undernourishment or nutritionally inferior diets. Recent research by Bitler et al. (2020) showed that even in advanced economies like the US, an insufficiently developed social protection system can let many fall through the holes of the safety net and contribute significantly to exorbitant food insecurity. In our analysis, we find that social protection is indeed effective in reducing undernourishment, as a typical change in social protection spending leads to a 0.24 percent reduction in the prevalence of undernourished with no effects on diet composition. In our heterogeneity analysis, we showed also that social protection acts also indirectly by reducing the real income elasticity of undernourishment thus acting like a shock absorber during economic downturns. Using social protection countercyclically poses some challenges related firstly to the availability of resources to scale up schemes during downturns, and secondly to the difficulties of implementing dynamic targeting of programs to increase coverage as needed, by including the newly food insecure which previously did not fall under this category.

The finding that real income per capita and income support measures on one side and food inflation the other side are jointly influential for food security, has important implications for social protection policies. To preserve the purchasing power of the most vulnerable, governments should aim at the adequate and timely indexing of cash benefits to food or headline inflation. When food security is the primary objective of the program, in kind transfers can be used as an alternative to, or in combination with cash, since they offer a natural insurance against commodities price fluctuations. Finally, we find little to no evidence of convergence among countries resulting in a persistently large gap between advanced economies that have eliminated food insecurity long ago on one side and middle- and low-income countries that despite considerable progress in the last couple of decades still lag behind on the other side.

Overall, our analysis shows that food insecurity reacts to short-term fluctuations of economic activity and to food inflation. Our heterogeneity analysis along structural characteristics of the national economies showed that while in the long run economic growth and inclusiveness appear to be universal remedies against undernourishment, in the short run, governments should use social safety nets to assure a smooth process and protect the most vulnerable along the bumpy road to zero hunger.

Declaration of Interest

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Appendix

TABLE A1: Estimation results of interaction equation for PoU

	FD-IV	First stage
y_0	-0.002	146.52
	(0.006)	(0.000)
Δ ln GDP pc	-0.601	9.85
	(0.433)	(0.000)
Δ Food inflation	0.035	6.35
	(0.061)	(0.000)
Δ ln Social transfers	-0.021***	7.82
	(0.007)	(0.000)
GDP pc	-0.000	140.78
	(0.000)	(0.000)
Share of SP	0.279	152.29
	(0.232)	(0.000)
Food imp ratio	0.031	7.59
	(0.081)	(0.000)
Bottom 20	0.017	16.49
	(0.033)	(0.000)
Δ ln GDP pc \times GDP pc	0.008	9.14
	(0.008)	(0.000)
Δ ln GDP pc \times Share of SP	3.178	9.81
	(2.647)	(0.000)
Δ ln GDP pc \times Food imp ratio	1.032	4.98
	(0.753)	(0.000)
Δ ln GDP pc \times Bottom 20	-5.489	7.5
	(3.905)	(0.000)
_cons	-0.033**	
	(0.016)	
N	1696	
Overidentification test	69.9	
(P value)	(0.28)	

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last column shows the F test statistics from the first stage of each regressor and its p value.

TABLE A2: Estimation results of interaction equation for diet composition

	CER	PROT	First stages	
y_0	-0.001	-0.004	80.27	143
	(0.009)	(0.006)	(0.000)	(0.000)
Δ ln GDP pc	-0.077	0.834***	11.02	11.02
	(0.184)	(0.270)	(0.000)	(0.000)
Δ Food inflation	-0.009	-0.095***	7.08	7.08
	(0.026)	(0.037)	(0.000)	(0.000)
Δ ln Social transfers	-0.000	-0.001	1.8	1.8
	(0.005)	(0.008)	(0.000)	(0.000)
GDP pc	-0.000	-0.000	136.47	136.47
	(0.000)	(0.000)	(0.000)	(0.000)
Share of SP	0.042	0.028	156.15	156.15
	(0.039)	(0.048)	(0.000)	(0.000)
Food imp ratio	0.050**	0.005	8.08	8.08
	(0.024)	(0.028)	(0.000)	(0.000)
Bottom 20	-0.023	-0.018	14.04	14.04
	(0.079)	(0.112)	(0.000)	(0.000)
Δ ln GDP pc \times GDP pc	0.008	0.000	8.47	8.47
	(0.006)	(0.006)	(0.000)	(0.000)
Δ ln GDP pc \times Share of SP	-0.658	-2.446*	8.89	8.89
	(1.210)	(1.426)	(0.000)	(0.000)
Δ ln GDP pc \times Food imp ratio	-0.717	-0.217	6.23	6.23
	(0.436)	(0.645)	(0.000)	(0.000)
Δ ln GDP pc \times Bottom 20	-0.679	-0.683	8.37	8.37
	(1.453)	(2.015)	(0.000)	(0.000)
_cons	-0.006	0.008		
	(0.010)	(0.016)		
N	1662	1662		
Overidentification test	88.91	71.39		
(P value)	(0.02)	(0.25)		

Note: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last column shows the F test statistics from the first stage of each regressor and its p value.

TABLE A3: Effects of sectoral composition of growth

	FD	FD-IV	First stage
y_0	-0.000	-0.000	
	(0.000)	(0.000)	
Agr. growth	-0.025	0.080	9.72
	(0.019)	(0.075)	(0.000)
NonAg growth	-0.268***	-0.648***	18.59
	(0.066)	(0.214)	(0.000)
Δ Food inflation	0.042*	0.115	18.53
	(0.025)	(0.079)	(0.000)
Δ ln Social transfers	-0.012***	-0.029**	8.76
	(0.003)	(0.013)	(0.000)
_cons	-0.007***	0.005	
	(0.002)	(0.005)	
N	1994	1723	
Overidentification test		4.87	
(P value)		(0.30)	

[a] **Note**: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The last two columns show the F test statistics from the first stage of each regressor and its p value.