The income-elasticity of calories, macro and micro nutrients: What is the literature telling us?

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Abstract

Food security and nutrition have become central to the policy agendas of governmental and non-governmental organizations due to their consequences on health and economic development. Changes in consumption patterns in response to price and income changes could impact on nutrient intake with related positive or negative consequences. This article aims to systematically review the elasticity of calories, macronutrients and micronutrients to income in developing and developed countries. We consider a large set of estimates on income elasticity for calories, protein, fat, zinc, iron and vitamin A. This is one of the few reviews that examines the estimates for income elasticity of calories, micronutrients, and micronutrients on a comparative basis. Moreover, we investigate the determinants of the heterogeneity in estimates by means of a rigorous and popular approach of meta-analysis. We found a substantial publication bias, and, in particular, we found that the quality of data is very important as it is able to influence estimates.

Keywords: Calorie; Food Security; Income Elasticity; Meta-Analysis; Nutrient

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1. Introduction

In recent times food security, malnutrition and related consequences on health and economic development has received global attention (e.g. Wals et al., 2014; Machlis, 2015; Santeramo, 2015). This attention has been highlighted by the Lancet's Series on Maternal and Child Nutrition 2008 and 2013. The 2008 series emphasized the need for adequate child and maternal nutrition to promote optimal child growth including cognitive development with possible long-term consequences on economic development for affected countries (Victora *et al.*, 2008). By limiting cognitive development and physical capacity, micronutrient deficiencies can affect the quality of human capital and impact on poverty and economic development. The most effective interventions to address child and maternal malnutrition have been identified and include addressing micronutrient deficiencies, especially iron, zinc, vitamin A and iodine, as well as addressing nutrition sensitive agriculture (Bhutta *et al.*, 2008; Ruel *et al.*, 2013). Nutrition-sensitive agriculture is important because of its role in making nutritious food available to households for adequate nutrition and food security. However, not all the food consumed by households is produced by households, even where subsistence farming is the norm. Economic access to food through food markets is, therefore, an important aspect in meeting adequate nutrition (FAO, IFAD and WFP, 2013) but this, in turn, is affected by food price dynamics. A systematic review with meta-regression that included 136 studies conducted in both developed and developing countries demonstrated that food consumption in poor countries was more sensitive to price changes than in developed countries (Green *et.al.*, 2013). This is because people in developing countries ordinarily spend a much higher proportion of the household income on food. Diets in developing countries are largely starch based in terms of calories, although many of them derive their protein form plant based sources. People in developing countries would, therefore, be expected to be most vulnerable to changes in related nutrient intakes in response to increased food prices as they substitute more expensive foods like animal source foods with cheaper less nutrient dense staples. The resulting reduction in dietary diversity could impact negatively on nutrient adequacy, especially with respect to micronutrients intake. Ruel (2003) conducted a review of studies that used dietary diversity methodologies as an indicator of diet quality and found that, regardless of the approach used, dietary diversity was positively associated to nutrient adequacy even in poor developing countries.

Although the most severely food insecure people will most definitely be underweight and starving, overweight and obesity may also be caused by food insecurity: research has shown associations between low socioeconomic status and prevalence of overweight and obesity (Martin-Fernandez *et al.,* 2014). There is evidence that by means of economic development, developing countries experience changes in food consumption patterns (Vorster *et al*., 2011) and that the resulting nutrition transition is driven by better economic access to different foods at household level. Some of the changes that take place are positive, e.g. the increasing consumption of animal source protein leading to higher micronutrient intakes like iron, zinc and vitamin A. On the contrary, other changes in dietary patterns are detrimental to health outcomes. Examples include increased calorie consumption from saturated fat and simple sugars, both associated with increased risk of overweight, obesity and other non-communicable diseases (NCDs) (Vorster *et al*. 2011). A recent review of studies conducted in several Sub-Saharan African Countries has shown an increase in terms of overweight individuals in the population of the Countries under consideration (Steyn and Mchiza, 2014). Micronutrient deficiencies place a significant burden on the national health costs of developing countries making policy intervention an important consideration to mitigate effects of food price volatilities especially in vulnerable countries.

Briggs et al. (2013) conducted a modelling study that explored the effect of a 10% tax on sugar sweetened beverages on obesity in Ireland. The authors reported finding a small but meaningful effect especially for adults aged 24-34. Although the effect identified by this study was small, the fact that the model only included sugar sweetened beverages should be taken into consideration. Other high sugar containing foods like confectionaries, as well as high fat food items, are also important determinants of obesity. Another study by Claro et al., (2012) found that a tax on sugar-sweetened beverages in Brazil reduced consumption especially for the poor. In the US, food and nutrient price elasticity has been reported to have the potential to influence nutrient intake through substitution of foods, as families adjust eating patterns to cope (Miao *et al*., 2013). Similar effects have been reported in Africa (Akinleye and Rahji, 2007; Abdulai and Aubert, 2004a) and Asia (Skoufias *et al*., 2012). Deaton and Dreze (2010) reported that calorie intake in India has declined over time, thus keeping prices steady, probably due to continuous improvements in health conditions over time. Changes in consumption patterns due to price changes, regardless of how they are introduced they come about (taxes, local or international price volatility), could impact on nutrient intake and bring about positive or negative consequences. It is not yet clear to what extent such price changes would affect specific nutrient intakes in developing countries. Furthermore, the important role of micronutrients like iron, zinc and vitamin A, protein and energy on health warrant a closer look at the effect of price elasticity on their intakes.

The debate regarding calorie-income relationship is well documented in literature (*cfr.* Zhou and Yu, 2015 for a recent review), whereas there is limited research on the relationship between income and key macro and micro nutrients. Several authors such as Bouis and Haddad (1992), Grimard (1996), Subramanian and Deaton (1996), Gibson and Rozelle (2002), Aromolaran (2004a; 2004b), and Abdulai and Aubert (2004a; 2004b) reported the strong relationship between level of per capita expenditure and calorie consumption. On the contrary, Behrman and Wolfe (1984), Behrman and Deolalikar (1987), Bouis (1994), and Skoufias et al. (2012) argued that the relationship between household income and calorie intake is not significantly different from zero. These authors concluded that income subsidizing policies will have limited impact on nutritional policies. A further aspect that deserves to be mentioned is the curve of the relationship between income and nutrient consumption. According to Engel's Law as income increases, the proportion of income spent on food decreases. Moreover, Bennett's Law states that as income increases, households change the allocation of food budget, thus shifting from starchy staple food that are inexpensive source of calories to more expensive food such as fruits and animal products that are rich sources of nutrients. The changing behaviour in diet as function of income is likely to be captured by non-linear specification of household food commodities and nutrients demand functions (e.g. Abdulai and Aubert, 2004a; Ecker and Qaim, 2011).

The literature on income elasticity in relation to calories is extensive, while few studies present income-elasticities for nutrients. In both cases there is a large heterogeneity in estimates due to differences in research designs, or temporal and spatial dynamics. Indeed many factors tend to influence empirical estimates of income elasticity to nutrients intake: our article aims to systematically review the elasticity of calories, macronutrients and micronutrients to income. In particular we consider a large set of estimates on income elasticity for calories, protein, fat, zinc, iron and vitamin A. The analysis includes studies conducted in developed and developing countries. While previous studies have revised impacts of income on calories intake and on consumption of categories of food (e.g. Ogundari and Abdulai, 2013; Gandhi and Zhou, 2014), to the best of our knowledge this is the first review that examines the estimates for income elasticity of calories, micronutrients, and micronutrients on a comparative basis. Moreover we investigate the determinants of the heterogeneity in estimates by means of a rigorous and popular approach: meta-analysis. Moreover we test for biases in estimations induced by models, publication type, and data quality in order to provide suggestions on the reliability of estimates provided by official publications' estimates. The information generated may have food pricing policy implications to mitigate possible consequences on nutrient intakes and related health consequences.

2. *Dataset and preliminary analysis*

The data employed in the present analysis include numerous studies and estimates on income elasticity. Papers have been collected through most relevant websites for the purposes of the present paper, i.e., Web of Science, Scopus, and Google Scholar. The latter allowed us to cover gray literature (working papers and discussion papers) in order to make sure that that publication bias and the effects of factors such as the journal prestige, and its impact factor can be correctly identified. The studies have been selected according to the presence of information on sample sizes, elasticity, and the associated standard errors or t-values. The inclusion criteria led us to select 26 studies in total (table 1). However, the number of observations is larger since some studies include several estimates that differ for type of estimation, subpopulation, or nutrient of reference. Far from being comprehensive, our study includes more than 100 observations, resulting in a benchmark for future investigations.

TABLE 1 – Studies for the meta-analysis and comparative statistics (elasticities in parenthesis)

Author	Year	Publication Outlet	Country	Elasticity
Akinleye and Rahji	2007	Agrekon	Nigeria	Calorie (-3.13), Protein (-1.3), Fat (-14.4), Iron (-2.9)
Abdulai and Aubert	2004	Food Policy	Tanzania	Calorie (0.52)
Abdulai and Aubert	2004	Agricultural Economics	Tanzania	Calorie (0.42), Protein (0.43), Fat (0.92), Iron (0.30), Zinc (0.46), VitaminA (0.38)
Aromolaran	2004	Food Policy	Nigeria	Calorie (0.19)
Babatunde et al.	2010	Agriculture Science	Nigeria	Calorie (0.02)
Bahrgava	1991	Royal Statistical Society	India	Calorie (0.06), Protein (0.10), Iron (0.01)
Behrman and Deolaliker	1987	Journal of Political Economy	India	Calorie (0.17), Protein (0.06), Iron (-0.11)
Behrman and Deolaliker	1990	Journal of Human Resouce	India	Calorie (-0.04), Protein (-0.04), Iron (-0.06)
Behrman and Wolf	1984	Journal of Development Economics	India	Calorie (0.14), Protein (0.12), Iron (0.12),VitaminA (0.13)
Dimova et al.	2012	Working Paper	Bulgaria	Calorie (0.85), Protein (0.94) ,Fat (0.86)
Ecker and Qaim	2010	World Development	Malawi	Calorie (0.92), Protein (0.92), Iron (0.91), Zinc (0.91),VitaminA (0.82)
Gahia et al.	2012	Working Paper	India	Calorie (0.41), Protein (0.43), Fat (0.75)
Liaskos and Lazaridis	2003	Agriculture Economics Review	Greece	Calorie (0.28), Protein (0.28), Fat (0.39), Iron (0.18)
Gibson and Rozelle	2002	Journal of Development Economics	Papua New Guina	Calorie (0.52)
Grimard	1996	The Pakistan Development Review	Pakistan	Calorie (0.47)
Jha et al.	2006	Working Paper	India	Calorie (0.06), Protein (0.19), Iron (0.15)
Pereda and Alves	2008	Working Paper	Brazil	Protein (-0.01), Fat (-0.01)
Sinha	2005	Working Paper	India	Calorie (0.57)
Skoufias et al.	2009	Agriculture Economics	Mexico	Calorie (0.44)
Skoufias et al.	2012	World Bank Economic Review	Indonesia	Calorie (0.14), Protein (0.19), Fat (0.5), Iron (0.16), VitaminA (0.13)
Skoufias	2003	World Development Review	Indonesia	Calorie (0.45)
Subramanian and Deaton	1996	Journal of Political Economy	India	Calorie (0.36)
Timmer and Alderman	1979	Agriculture and Applied Economics Association	Indonesia	Calorie (0.47)
Torres	2013	Agriculture and Applied Economics Association	Mexico	Calorie (0.99), Protein (1.0), Iron (1.0), Zinc (1.0), VitaminA (1.0)
Ulimwengu et al.	2012	Working Paper	Congo	Calorie (0.68), Protein (0.64), Iron (0.66), Zinc (0.58), VitaminA (0.59)
Ye and Taylor	1995	Economic Development and Cultural Change	China	Calorie (0.28),Protein (0.22)

Moreover, we excluded studies in which the estimates were not explicitly considering one of the categories under consideration: calories, protein, fat, and micronutrients (zinc, iron and vitamin A). We have aggregated the income elasticities for iron, zinc and vitamin A for statistical and epistemological reasons: first the estimates for each micronutrient were less than 20 which renders it unfeasible to apply a meta-analysis; second t-tests revealed that the elasticity of iron and zinc was statistically not different, and the estimates for zinc are have higher mean but very similar variability (i.e. can be assumed to be a mean preserving spread transformation of iron and vitamin A distributions).

TABLE 2 – Descriptive statistics of the MRA sample

	Calorie	Protein	Fat	Micro
Mean	0.38	0.42	0.62	0.62
Median	0.37	0.27	0.63	0.30
Standard Deviation	0.27	0.33	0.29	0.34
Kurtosis	2.71	1.79	2.39	1.84
Observations	117	57	30	34

In Table 2 we present a summary of descriptive statistics of our dataset. It shows that on average income elasticity ranges from 0.38 to 0.62, with an even lower median value (between 0.27 and 0.63). In other words, calories and nutrients tend to be income-inelastic.

The next paragraph is devoted to illustrate the methodological approach we have followed to review the literature and to gain further insights.

3. *Methodology*

Meta-analysis is becoming increasingly popular in economics, and it has been applied to review decades of research on several topics: trade (Disdier and Head, 2008; Cipollina and Salvatici, 2010; Havranek, 2010; Li and Beghin, 2012), price elasticity of demand (Espey, 1998; Dalhuisen et al., 2003; Gallet and List, 2003; Knell and Stix, 2005; Gallet, 2010;), technical efficiency and factor productivity (Bravo-Ureta et al., 2007; Tian and Yu, 2012), income inequality and economic growth (Doucouliagos, 2005; de Dominicis et al., 2008), food safety (Totton et al., 2012; Xavier, 2014). Recently, attention has been also paid to calorie-income elasticity (Ogundari and Abdulai, 2013), a topic of great interest for its potential policy implications.

A preliminary outcome of the meta-analysis, and indeed a very important step itself, consists in identifying the existence of publication bias. Publication bias may be generated by several factors: preference by authors, reviewers, and editors for statistically significant results to the detriment of studies that report insignificant estimates (Stanley, 2005). The latter, if published, pay the toll of providing no statistically significant results, in terms of collocations in less prestigious journals. A systematic way to address the issues has been proposed by Egger et al (1997): they suggested to apply funnel asymmetry tests (FAT) to the meta-regression analysis (MRA). The FAT-MRA consists in regressing the effect size (η_i) of the phenomenon of interest on a measure of the precision of estimates, and other covariates:

$$Effect\ size\ _i = f(Estimate\ precision_i, Control\ variables_i) \qquad (1)$$

A common functional form for equation 1 is the linear form, so that the equation can be estimated through least squares. We will follow the conventional wisdom here, and replace equation 1 with a linear specification. Let us denote the effect size by η, the measure of precision (or dispersion) by Δ, and the likelihood of acceptance by $\mathcal{L}$. On the right hand side of equation 1 we will consider two sets of covariates, respectively capturing the heterogeneity in estimates, and the publication bias. The former set includes k regressors (Ω_k) able to influence the estimates ($Corr(\Omega_{k,i}, \eta_i) \neq 0$), but uncorrelated with the likelihood of acceptance ($Corr(\Omega_{k,i}, \mathcal{L}_i) = 0$). The second set of m regressors (Ψ_m) includes variables that are likely to influence the acceptance of the paper for publication ($Corr(\Psi_{m,i}, \mathcal{L}_i) \neq 0$), but are not informative for the estimates ($Corr(\Psi_{m,i}, \eta_i) = 0$). Following Stanley (2005), our measure of dispersion will be the standard errors of the estimates ($\Delta_i \equiv \sigma_i$). The resulting model, and the null hypothesis to test whether the estimates are affected by publication bias are as follows:

$$\eta_i = \alpha_0 + \alpha_1 \Delta_i + \sum_{i=1}^{K} \delta_k \Omega_{k,i} + \sum_{i=1}^{M} \pi_m \Psi_{m,i} + \varepsilon_i \qquad (2)$$

$H_0: \alpha_1 = 0$ vs $H_0: \alpha_1 \neq 0$

A drawback of the above presented approach is that it suffers for the heteroskedasticity of estimates. We correct this embedded heteroskedasticity by using the inverse of the standard errors, and dividing the dependent variable by the standard errors ($t - stat$) and the set of k regressors (Ω_k) by the standard errors. The specification will be as follows:

$$tstat_i = \alpha_1 + \alpha_2 \frac{1}{\sigma_i} + \sum_{i=1}^{K} \delta_k \Omega_{k,i}/\sigma_i + \sum_{i=1}^{M} \pi_m \Psi_{m,i} + \varepsilon_i \qquad (3a)$$

(i) $H_0: \alpha_1 = 0$ vs $H_0: \alpha_1 \neq 0$

(ii) $H_0: \alpha_1 = 0$ vs $H_0: \alpha_1 \neq 0$

The rationale of the test (i) is that the larger the deviation of α_1 (*Publication bias*) from zero, the larger the publication bias. Moreover, the coefficient α_2 (*Empirical Effect*) inform us of the significativity of income on elasticity, which means that if α_2 is statistically significant (test ii) we conclude that the influence of income on the elasticity is statistically different from zero in the reviewed studies. Finally, we test for the meta-significance (MST) of the meta-analysis by estimating equation 3b:

$$tstat_i = \alpha_1 + \alpha_2 \ln(\mathrm{n}) + \sum_{i=1}^{K} \delta_k \Omega_{k,i} / \sigma_\mathrm{i} + \sum_{i=1}^{M} \pi_m \Psi_{m,i} + \varepsilon_i \qquad (3b)$$

(i) $H_0\colon \alpha_1 = 0$ vs $H_0\colon \alpha_1 \neq 0$

(ii) $H_0\colon \alpha_1 = 0$ vs $H_0\colon \alpha_1 \neq 0$

where $\ln(\mathrm{n})$ is the logarithm of the sample size. Analogously to the previous test, if $\alpha_2$is statistically significant (test ii) we conclude that the influence of income on the elasticity is statistically different from zero. The interpretation of $\alpha_1$is unaltered.

As a second step for our analysis, we use meta-regression analysis (MRA) to explain the source of heterogeneity in income elasticity of nutrients. A typical MRA can be specified as follows:

$$\eta_{ij} = \alpha + \sum_{i=1}^{K} \delta_k \Omega_{k,ij} + \sum_{i=1}^{M} \pi_m \Psi_{m,i} + \varepsilon_{ij} \qquad (4)$$

where the i-th elasticity of the j-th study is explained by the set of regressors k regressors (Ω_k) and the set of m regressors (Ψ_m). Following Stanley (2008), we estimate Equation 4 by means of Weighted Least Square in order to reduce the effect of publication bias in meta-regression analysis. The weights need to be correlated with the size of the studies, therefore, the inverse of the square root of the standard errors of the estimated effect size are appropriate weights. The approach is similar to that in Ogundari and Adbulai (2013) who weighted by using the inverse of the variance of the standard error of the effect size.

In order to explain the heterogeneity in estimates of income elasticity, we consider several explanatory variables related to the methods of estimation, the number of observations, the location of the study, the prestige of the journal hosting the publication etc. The variables adopted in our study are listed and described in Table 3. The set of k regressors (Ω_k) includes the variables *"Income", "Linear", "Q-AIDS",* and *"Number of Years"*, while the set of m regressors (Ψ_m) includes the variables *"Panel", "Weekly", "Monthly", "Rural", "Africa", "Asia", "South America", "Unpublished Paper",* and *"Impact Factor".*

TABLE 3 – Description of the variables

Category	Variables	Description
Model	Income	Dummy variable: 1 if income is adopted (0 for expenditure)
	Linear	Dummy variable: 1 if linear model is adopted (0 otherwise)
	Q-AIDS	Dummy variable: 1 if Q-AIDS model is adopted (0 otherwise)
Prestige	Unpublished Paper	Dummy variable: 1 if gray literature (0 otherwise)
	Impact Factor	Dummy variable: 1 if the reviews has IF (0 otherwise)
Population	Rural	Dummy variable: 1 if referred to rural population (0 otherwise)
	Africa	Dummy variable: 1 if referred to Africa (0 otherwise)
	Asia	Dummy variable: 1 if referred to Asia (0 otherwise)
	South America	Dummy variable: 1 if referred to South America (0 otherwise)
Data	Panel	Dummy variable: 1 if panel data (0 otherwise)
	Number of Years	Count variable: Number of years considered in the study
	Sample_size	Continuous variable: Number of observations in the study
	Weekly	Dummy variable: 1 if data have weekly frequency (0 otherwise)
	Monthly	Dummy variable: 1 if data have monthly frequency (0 otherwise)

Q-AIDS: Quasi—almost ideal demand system. The model is a workhorse in demand estimation.

4. Results

As first step, we can comment the results on the FAT-MRA analysis, obtained through equation 2. The results are omitted from the article for space limitation, and are available upon request. In particular we are interested in assessing whether the coefficient α_1 is statistically significant or not. In all cases (calorie, protein, fat and micronutrients) the coefficient is statistically different from zero, but the largest biases are observed for protein and fat. This preliminary results suggest that the publication bias may be an issue for the sizes of the effect. In order to correct the potential heterogeneity, we have estimated equation 3, and the results are reported in Table 4. The results are robust to heterogeneity in that the dependent variable and the set of k regressors (Ω_k) are normalized by the standard errors. The results show that the bias is detected only for protein and fat (at significance level of 5% or lower): the former shows a negative bias ($\alpha_1 = -1.6$), while the latter has a positive bias ($\alpha_1 = 7.1$). We also found that only for protein and fat the coefficient α_2 is statistically significant. We can conclude that the effect of income is relevant to the elasticity of protein and fat reported in the articles and working papers considered in the present analysis. In the other two cases (calories and micronutrients) the effect of income is negligible, which means elasticity tend to be constant, regardless of income level.

TABLE 4 - FAT-PET-MRA results: Equation 3a

	Calorie	Protein	Fat	Micro
α_1	253.992	-1.680	7.180	-0.190
	(1.76)+	(2.31)*	(35.81)**	(0.08)
α_2	-0.058	1.400	-0.208	0.009
	(0.38)	(3.57)**	(10.88)**	(0.03)
Set of Ω regressors	YES	YES	YES	YES
Set of Ψ regressors	YES	YES	YES	YES
R^2	0.97	0.97	0.99	0.91
Observations	63	33	18	19

Note: t-stats in parenthesis; +, *, and ** indicate statistical significance at 10, 5 and 1 percent respectively.

Table 5 presents the results of equation 3b and allow to strengthen (or weaken) previous findings. We found further evidence that the influence of income on elasticity is statistically different from zero for protein and fat. The results of tables 3 and 4 are not surprising, but of particular interest for potential policy implications. We shall discuss them later.

TABLE 5 - MST-MRA results: Equation 3b

	Calorie	Protein	Fat	Micro
α_1	-237.012	-2.359	-15.845	3.087
	(1.55)	(0.73)	(23.43)**	(1.09)
α_2	200.390	0.811	2.193	-0.103
	(1.98)+	(1.85)+	(35.00)**	(0.30)
Set of Ω regressors	YES	YES	YES	YES
Set of Ψ regressors	YES	YES	YES	YES
R^2	0.96	0.93	0.99	0.81
Observations	63	33	18	19

Note: t-stats in parenthesis; +, *, and ** indicate statistical significance at 10, 5 and 1 percent respectively.

Table 6 presents the estimates obtained from equation 4. The results show that the elasticity for calories is lower when we adopt household income rather than the expenditure. It is interesting to note that by adopting a Q-AIDS model the elasticity tend to be higher, exception made for fat.

The results also provide explanation on how publication bias tends to distort the estimates: the income-elasticity reported in articles published in journals are lower than those reported in working/discussion papers; it is also lower for articles published in journals with impact factor.

The variables "Rural" and *"Continent"* show statistically significant albeit negligible effects. The results on the quality of data are very interesting. Almost in all cases we found that detailed information is associated with larger estimates. For instance, the variable *"Panel"* is statistically significant and positive. Exception made for fat elasticity. However, in this case albeit the coefficient is negative the significance level is 10%. Similarly, by adopting data at high frequencies (e.g. monthly or weekly) it is likely that higher estimates are obtained. Finally, larger sample sizes may lead to larger or lower estimates, depending on the nutrient considered: elasticity is higher for protein and micro-nutrients, and lower for fat.

TABLE 6 - MRA results – Weighted regression: Equation 4

	Calorie	Protein	Fat	Micro
Income	-0.286	2.047		-0.178
	(3.91)**	(1.55)		(1.68)
Linear	-0.040	-0.030	0.115	-0.006
	(1.07)	(0.84)	(8.00)**	(0.07)
Q-AIDS	0.645	0.789	-4.379	0.650
	(6.82)**	(3.75)**	(5.79)**	(6.33)**
Number of Years	-0.068	-1.699	2.573	
	(2.80)**	(2.30)*	(5.88)**	
Unpublished Paper	0.356	-3.182		
	(5.15)**	(1.65)		
Impact Factor	-0.140	-0.890		-0.201
	(3.23)**	(1.79)+		(2.20)*
Rural	-0.022	0.005	0.175	0.016
	(0.63)	(0.13)	(12.18)**	(0.26)
Africa	-0.178			
	(2.17)*			
Asia	0.054			
	(0.73)			
South America	0.084	-0.637		0.347
	(0.98)	(1.29)		(2.61)*
Panel	0.339	2.469	-0.413	0.546
	(4.55)**	(2.35)*	(2.07)+	(4.13)**
Weekly	0.226			0.013
	(1.95)+			(0.09)
Monthly	0.092	3.226	2.048	
	(0.85)	(1.84)+	(8.51)**	
Ln(Sample_size)	-0.015	1.151	-1.146	0.097
	(1.07)	(2.05)*	(5.75)**	(2.65)*
Constant	0.488	-6.439	5.234	-0.669
	(2.59)*	(1.85)+	(5.92)**	(1.77)+
R^2	0.76	0.96	0.99	0.87
Observations	117	57	30	34

Note: t-stats in parenthesis; +, *, and ** indicate statistical significance at 10, 5 and 1 percent respectively.

5. Conclusions

Food security and nutrition have become central to the policy agendas of governmental and non-governmental organizations due to the consequences that they can generate on health and economic development. Changes in consumption patterns in response to price and income changes could impact on nutrient intake with related positive or negative consequences. A vast empirical literature provides estimates of income elasticity of calories, micro and macro nutrients. However, the elasticities reported in different studies are very heterogeneous. Moreover, due to the empirical and political implications that reported estimates on income elasticity may have, understanding the determinants of the heterogeneity in estimates is of great relevance.

Our meta-analysis found that in the majority of studies calories and proteins are found to be more income-inelastic than fat and micronutrients, which have been found to be more sensitive to income changes. Our meta-analysis found that the influence of income on their elasticity is statistically different from zero. To the extent that adequate child and maternal nutrition have been proved to promote optimal child growth and have positive consequences on economic development (Victora *et al.*, 2008), our results strengthen the importance of implementing policies aimed at improving diet quality and affordability of food. Our results are, therefore, in line with previous studies (Bhutta *et al*., 2008; Ruel *et al*., 2013). Moreover, we found a substantial publication bias for sizes of effect that has deserved a deep investigation. For calories, we found that the income-elasticity reported in articles published in journals and particularly in articles published in journals with impact factor tend to be lower that those published in working and discussion papers, thus warning about the reliability of conclusions supported solely by official publications' estimates. Finally, we found that the quality of data is very important and able to influence estimates.

There may be some limitations to this study, as for instance, the number of studies taken into account that may be considered scant. However, relying on a larger set of studies for the present meta-analysis does not seem to be feasible, due to the nature of our investigation. As a matter of fact, there is a limited number of studies available regarding income-elasticity for protein, fat and micronutrients. Understanding the impact of income changes on nutrients intake remains an important topic deserving further research.

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