منظمة
الأغذية والزراعة
للأمم المتحدة

联 合 国
粮 食 及
农 业 组 织

Food and Agriculture
Organization of the
United Nations

Organisation des
Nations Unies pour
l'alimentation et
l'agriculture

Продовольственная и
сельскохозяйственная
организация
Объединенных Наций

Organización de las
Naciones Unidas para la
Agricultura y la
Alimentación

FAO Regional Office for Europe and Central Asia

Policy Studies on Rural Transition No. 2013-7

The triple burden of malnutrition in Europe and Central Asia: a multivariate analysis

Sara Capacci
Mario Mazzocchi
Bhavani Shankar
Bruce Traill

2013

Mario Mazzocchi is associate professor, Sara Capacci is researcher at the University of Bologna, Department of Economics, Bhavani Shankar is professor at the University of London, Leverhulme Centre for Integrative Research on Agriculture and Health and SOAS and Bruce Traill is professor at the University of Reading, School of Agriculture, Policy and Development. This background paper was commissioned by FAO Regional Office for Europe and Central Asia as part of a study on malnutrition in Europe and Central Asia.

Contents

Abstract

Based on an ample country-level data set compiled from various official sources and a set of multivariate statistical methods, we analyse the geography of the three malnutrition dimensions (undernutrition, overnutrition and micronutrient deficiencies) in Europe and Central Asia countries, with two objectives: (a) provide a mapping of the current state of malnutrition in the region; (b) explore how different malnutrition contexts can be associated with socio-economic determinants, and how they translate into health and economic burdens.

1. Introduction

The complex interaction between economic development, the evolution of food systems and malnutrition outcomes (FAO, 2013) is the key to effective policy interventions targeted at reducing the social and economic burden of nutrition-related diseases. Thus, it is first necessary to recognise the heterogeneity of outcomes and causes across and within countries. This study aims at exploring such heterogeneity in Europe and Central Asia (ECA), by combining national-level data from various official sources and through the application of multivariate statistical methods for data reduction and classification.

Over the last two decades, the world has not witnessed the expected reduction in the absolute number of chronically hungry people. Despite the contribution of economic growth in reducing the prevalence of undernutrition, demographic growth and persisting disparities have prevented the eradication of undernourishment. Even in those countries where a higher calorie availability has mitigated food security problems, malnutrition persists in term of micronutrient deficiencies. A third dimension of malnutrition, associated with the rising prevalence of overweight and obesity and overnutrition-related diseases, is not an exclusive concern of high-income countries, and generates an additional health burden in many middle-income and even low income countries. The persistence of undernutrition and micro-nutrient deficiencies in areas where the prevalence of excess weight is also growing has been associated with economic transitions (Popkin, 2006), growing income inequalities, and rapid changes in the structure of food systems (FAO REU, 2012).

We explore the geography of these three malnutrition dimensions within the Eurasian continent, with two objectives: (a) provide a mapping of the current state of malnutrition in Europe and Central Asia; (b) explore how different malnutrition contexts can be associated with socio-economic determinants. A systematic data collection exercise, considering internationally comparable data from FAO, the World Bank, the World Health Organization, and the Institute of Health Metrics and Evaluation (Global Burden of Disease project), has led to the compilation of a data-set with 51 variables measured in 50 ECA countries, and covering the domains of malnutrition outcomes, their social and economic burden, and a variety of drivers including economic factors, socio-demographics variables and a small set of measures concerning the food markets (price levels, volatility and net food import measures). Most of these variables were observed in three points in time (around 1990, 2000 and 2010), and the resulting data-set also includes more than 100 derived variables capturing dynamics across the last two decades. On this data-set, we apply various multivariate statistical methods to summarise heterogeneity across countries in the triple burden of malnutrition, and find association between these country-level differences and potential disparities in a variety of drivers. The data-set is described in Section 2 of this paper, while Section 3 illustrates the methods used in the analysis. Section 4 reports the results and some policy conclusions and research hypotheses are drawn in Section 5.

2. Data

The analysis is fully based on international and validated indicators provided by FAO, World Bank, WHO and the Institute for Health Metrics and Evaluation, the latter as part of the collaborative project on the Global Burden of Disease, which involves WHO as well as a multitude of local public and research institutions. The wide set of accessible variables has been restricted to those available for ECA countries for an adequate number of years (at least within the period 2000-2010). The resulting 51 indicators composing our working-dataset are listed in Table 1 and belong to five main domains:

1. Nutrition status (further divided into the three dimensions of undernutrition, overnutrition and micronutrient deficiencies)
2. Social and economic burden of malnutrition
3. Socio-demographic factors and others
4. Food market indicators
5. Economic factors

The analysis is mainly based on 2010 as the most recent information, however 1990 and 2000 values (or others neighboring years in some cases) were also collected where available, in order to compute some indicators of change over the last decade (growth rates, e.g. population, employment, etc.). For some variables whose latest published number did not refer to 2010 or with missing observations, an average over an adequately short and recent span of time is employed to approximate the true unobserved value, while still maintaining comparability. In some cases no averaging was feasible, given the lack of observations and the latest available figure was employed. This is the case for obesity and overweight prevalence indicators (2008 is the reference year as the latest comparable information) and for micronutrient deficiency indicators (for which 2004 is the latest available year). For what concerns the burden of malnutrition (disability adjusted life years – DALYs – associated with risk factors), we employ the most recent county-level estimates produced by the Institute of Health Metrics and Evaluation together with WHO, referring to 2010 and publicly available on the web.

Table 1. List of indicators by domain

Variable	Definition	Source	Years	Mean* (2010)	Std.Dev. (2010)
Overnutrition[a]					
OBESEMALE	Proportion of obese people (male)	WHO	2002-2008	21.31	5.15
OBESEFEMALE	Proportion of obese people (female)	WHO	2002-2008	24.05	5.35
OBESETOT	Proportion of obese people (total population)	WHO	2008	22.78	4.36
OVERMALE	Proportion of overweight and obese people (male)	WHO	2002-2008	59.36	8.42
OVERFEMALE	Proportion of overweight and obese people (female)	WHO	2002-2008	52.72	6.64
OVERTOT	Proportion of overweight and obese people (total population)	WHO	2008	55.95	6.31
Undernutrition					
UNDERN [b]	Prevalence of undernourishment (% of population)	WDI	1991-2000-2011	7.05	6.17
STUNTING	Children aged <5 years stunted (%)	WHO	Latest data (2005-2010)	9.00	7.41
CALADEQ	Average dietary energy supply adequacy	FSI	2000-2010	129.92	13.01
Micronutrient deficiencies [c]					
CHILDANAE	Proportion of pre-school age children with anaemia (Hb<110 g/L)	WHO	2004	22.35	13.23
PREGNANAE	Proportion of pregnant women with anaemia (Hb<110 g/L)	WHO	2004	24.57	11.45
WOMENANAE	Proportion of non-pregnant women with anaemia (Hb<120 g/L)	WHO	2004	20.86	11.16
CHILDVITA	Proportion of pre-school age Children with vitamin A deficiency (serum retinol <0.70 μmol/l)	WHO	2004	11.42	13.97
POPZINC	Proportion of population at risk of inadequate intake of zinc	HB	2004	16.95	14.04
Social and demographic factors					
POLSTAB	Political stability and absence of violence/terrorism V23	FSI	1996-2000-2010	0.32	0.74
LIFETOT	Life expectancy at birth, total (years)	WDI	2000-1990-2010	76.11	4.78
AGEING	Population ages 65 and above (% of total)	WDI	1990- 2000-2010	13.71	4.32
URBAN	Urban population (% of total)	WDI	2000-2010	66.75	15.78
GINI	Gini Index	WDI	2000-2010	31.50	5.10
LABFEM	Labor participation rate, female (% of female population ages 15+)	WDI	2000-1990-2010	51.39	7.92
UNEM	Unemployment, total (% of total labor force)	WDI	2000-2010	11.02	6.51
IMMIG	Net migration (number of immigrants minus the number of emigrants, including citizens and noncitizens, for the five-year period)	WDI	2010	6014.37	23755.17
HEALTHEXPPUB	Health expenditure, public (% of total health expenditure)	WDI	1995-2000-2010	65.78	15.99
Food markets indicators					
FOODIMP	Food imports (% of merchandise imports)	WDI	1990-2000- 2010	14.18	16.57
CERIMPDEP	Cereal import dependency ratio (cereal imports/(cereal production+cereal import-cereal export))	FSI	2000- 2010	37.13	33.85
PRICE	The Domestic Food Price Level Index (Food Purchasing Power Parity (FPPP)/ General PPP)	FSI	1991-2000-2010	1.35	0.29
PRICEVOL	Domestic Food Price Level Index Volatility	FSI	1995-2000-2010	32.46	30.34

Table 1 (continued). List of indicators by domain

Variable	Definition	Source	Years	Mean* (2010)	Std.Dev. (2010)
Economic factors					
VADDAG	Agriculture, value added (% of GDP)	WDI	1990 -2000-2010	6.00	5.78
VADDSER	Services, etc., value added (% of GDP)	WDI	1990-2000-2010	65.26	11.10
EMPLAG	Employment in agriculture (% of total employment)	WDI	2000-2010	12.50	13.48
EMPLSER	Employment in services (% of total employment)	WDI	2000-2010	62.57	12.25
EMPLIND	Employment in industry (% of total employment)	WDI	2000-2010	24.35	6.36
FDI	Foreign direct investment, net inflows (% of GDP)	WDI	2000-2010	0.49	24.10
GDP	GDP per capita, PPP (constant 2005 international $)	WDI	1990-2000-2010	20373.74	13570.55
GDPCHG	Average yearly GDP growth (% change 2000-2010)	WDI	2000-2010	3.23	2.71
NATRES	Total natural resources rents (% of GDP)	WDI	2000-1990-2010	4.69	10.50
Social and economic burden					
DALYBMI	DALYs due to high body-mass index	IHME	2000-1990-2010	3193.02	1147.19
DALYDEF	DALYs due to nutritional deficiencies	IHME	2010	354.77	295.35
DALYMALN	DALYs due to protein-energy malnutrition	IHME	2000-1990-2010	23.76	26.03
DALYMIC	DALYs due to micronutrient deficiencies	IHME	2010	331.01	275.50
Other variables					
CAL	Dietary Energy Supply	FSI	2000- 2010	3220.60	349.96
HEALTHEXP	Health expenditure per capita, PPP (constant 2005 international $)	WDI	1995-2000-2010	2140.56	1664.87
HEALTHEXPGDP	Health expenditure, total (% of GDP)	WDI	1995-2000-2010-	8.27	2.21
LIFEFEM	Life expectancy at birth, female (years)	WDI	2000-1990-2010	79.39	4.15
LIFEMALE	Life expectancy at birth, male (years)	WDI	2000-1990-2011	72.96	5.48
MIGST	International migrant stock (% of population)	WDI	2000-1990-2010	9.65	7.62
ODA	Net official development assistance and official aid received (constant 2010 US$)	WDI	2000-1990-2010	369695556	256640798
POP	Total Population	WDI	1990-2000-2010	17.98	27.46
RCI	Recommendation Compliance Index, based on FAOSTAT data	MBS	1990-2000-2010	0.93	0.05
URBANGR	Urban population growth (annual %)	WDI	1990-2000-2010	0.76	0.81
VADDIND	Industry, value added (% of GDP)	WDI	1990 -2000-2010	28.74	9.07

Notes:

(a) The latest data refer to 2008 instead of 2010
(b) The latest data refer to 2011 instead of 2010
(c) The latest data refer to 2004 instead of 2004

Acronyms:

WHO: World Health Organization global databases
FSI: FAO Food Security Indicators
IHME: Institute of Health Metrics and Evaluation (Global Burden of Disease Project)
WDI: World Bank World Development Indicators
HB: Hotz, C., & Brown, K. H. (2004). Assessment of the risk of zinc deficiency in populations and options for its control. International nutrition foundation: for UNU.
MBS: Our estimates based on Mazzocchi M., Brasili C., Sandri E., Trends in dietary patterns and compliance with World Health Organization recommendations: a cross-country analysis, «PUBLIC HEALTH NUTRITION», 2008, 11(5), pp. 535 – 540

3. Methods

The statistical analysis consists in the sequential application of Principal Component Analysis, Cluster Analysis and a set of other multivariate methods (including one-way ANOVA and multiple equation regressions) aimed at detecting significant association between the country groupings and the set of potential drivers. Principal Component Analysis (PCA) is applied on the sub-sets of the indicators listed in Table 1 with the dual objective of summarising the data and minimising the noise from measurement errors. A classification of ECA countries based on three latent components, one for each of the malnutrition dimension, was then obtained through Cluster Analysis. A descriptive analysis of the potential drivers across the clusters (based on both original indicators and extracted components) combined with one-way ANOVA testing provides a first characterisation of the clusters. We also explore how the different levels of malnutrition translate into social and economic burden as measured by DALY measurements. Finally, we estimate a system of regression equations to explore the links between the potential drivers and each of the malnutrition outcomes.

3.1. Principal Component Analysis

We adopt a straightforward application of principal component analysis to reduce the dimension of analysis and mitigate measurement errors. Having these objectives in mind, the method is applied within each domain of indicators, rather than on the whole data-set. This choice implies that correlations between indicators within each domain are considered in the component extraction process, while correlations between indicators belonging to different domains are not accounted for. This is desirable for our purposes, because it allows to maintain the information about correlations between the various dimensions of malnutrition, e.g. between undernutrition and micronutrient deficiencies, or also the statistical relationship between overnutrition and undernutrition, which – as explained – is likely to differ across country groups.

The same procedure was adopted on indicators about potential driving factors from three domains (social and demographic factors, food market indicators, and economic factors), even if the distinction here is slightly more subjective. Since the country classification step through Cluster Analysis is only based on the malnutrition components, and the relation between the classification and the driving forces may also be explored at the individual indicator level, the extraction of principal components has the mere objective of simplify interpretation.

Regarding the number of components retained, only one component was extracted for each of the three malnutrition dimension. This is easily justifiable given the small number of indicators included in each domain (6 for overnutrition, 2 for malnutrition, 5 for micronutrient deficiencies), and as reported in the next section the amount of original variance explained by the first component is well above the usually recommended thresholds. Instead, the number of components extracted from each of the three domains for driving factors was extended to all those component with an eigenvalue larger than 1, i.e. whose level of explained variance was higher than the average component. We also adopted a VARIMAX rotation strategy for these components, in order to make their labelling and interpretation easier.

3.2. Cluster Analysis

Cluster analysis for classification of ECA countries was based on the three correlated components corresponding to the three burdens of malnutrition. We adopt a two-stage procedure, where the number of groups is identified via an agglomerative hierarchical clustering method (Ward) on the basis of various indicators exploring the relation between variability within clusters and between clusters for each potential partitions (Cubic Clustering Criterion, Pseudo-F, and Pseudo-t^2). The ideal number of clusters *n* corresponds to a local maximum for the CCC and Pseudo-F criterions, while the Pseudo-t^2 should be small or at least show a large increase when moving to *n-1* clusters. Once the number of cluster is defined, non-hierarchical methods which allow for reallocation of units are to be preferred, and we adopt the *k*-means algorithm.

4. Results

4.1. The triple burden of malnutrition

Table 2 below summarises the results from three independent PCAs applied to the three sets of indicators, each corresponding to one of the burdens of malnutrition. Within each set, correlations between the original indicators are very high and one component explains a proportion of original variability well above the usual selection thresholds. The resulting components are correlated, as expected, and correlations are highly significant. More specifically, there are strong correlations between overnutrition and undernutrition (negative) and between undernutrition and micronutrient deficiencies, while the negative relationship between overnutrition and micronutrient deficiencies is less strong, but still significant.

The two-step clustering approach described in Section 3.2 was applied on the three malnutrition components. The non-hierarchical step (Ward algorithm) was not fully conclusive about the ideal number of cluster, indicating either 5 or 6 clusters[1]. We explored the two solutions based on outputs from the *k*-means stage. In both analyses Tajikistan (with very high values in the undernutrition and micronutrient deficiencies components, and a very low value for the overnutrition component) would form an one-country cluster, but was aggregated to a cluster with countries showing the same characteristics, although with a less extreme degree. Similarly, the 6 cluster solution generated a two-country cluster (Azerbaijan and Georgia), with some presence of overnutrition and a high level in the undernutrition and micronutrient deficiencies. Again, the distance to a cluster with countries with similar characteristics was small enough to suggest aggregation.

[1] The solution with 6 clusters was preferable in terms of CCC (positive value) and Pseudo-F (local maximum), but had a high value for the Pseudo-t decreasing in the next step. Vice versa, the 5 cluster solution was more acceptable.

Table 2. Principal component analysis on malnutrition variables: loadings and correlations

Indicator	*Component loadings* Overnutrition	Undernutrition	Micronutrient deficiencies
OBESEMALE	0.83		
OBESEFEMALE	0.81		
OBESETOT	0.99		
OVERMALE	0.82		
OVERFEMALE	0.85		
OVERTOT	0.99		
UNDERN (2000)		0.87	
UNDERN (2011)		0.95	
CALADEQ		-0.60	
STUNTING		0.80	
CHILDANAE			0.93
PREGNANAE			0.95
WOMENANAE			0.87
CHILDVITA			0.94
POPZINC			0.60
% of variability explained	78%	66%	75%
Bivariate correlations of resulting components			
Overnutrition	1	-0.61**	-0.37**
Undernutrition		1	0.62**
Micronutrient deficiencies			1

** Significant at the 99% confidence level

In short, both analyses led to the identification of four groups of countries. We opted for the classification generated from the 6-cluster result, as it resulted in better goodness-of-fit diagnostics and showed a high degree of overlapping with the world-level classification described in SOFA (FAO, 2013, pag. 21), contrarily with the 5-cluster solution which seemed much less informative[2].

Table 3 reports the results of the cluster analysis, together with a comparison between the classification on ECA countries only as produced by the cluster analysis and the FAO classification (FAO, 2013). The 50 ECA countries correspond to members of FAO-REU (San Marino, Monaco, Andorra were excluded because of data gaps) are subdivided in four major ‘malnutrition’ regions:

1. *Undernutrition.* Countries with persisting undernutrition and micro-nutrient deficiencies, and relatively low overnutrition issues (Azerbaijan, Georgia, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan)
2. *Triple burden of malnutrition.* Countries where undernutrition persists and coexists with major prevalence of micronutrient deficiencies relatively higher levels of overnutrition (Albania, Armenia, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Kazakhstan, Macedonia, Moldova, Montenegro, Romania, Serbia, Ukraine)
3. *Overnutrition.* Countries where malnutrition and micro-nutrient deficiencies are around or below the overall ECA average, while overnutrition is relatively higher than in other ECA

[2] Tabulations and results from this alternative classification are available from the Authors

countries (Belarus, Czech Republic, Germany, Hungary, Ireland, Israel, Latvia, Lithuania, Luxembourg, Malta, Poland, Portugal, Russian Federation, Slovakia, Slovenia, Spain, Turkey, United Kingdom)

4. *Less concerned by malnutrition issues.* Countries where all malnutrition dimensions are well below the average across ECA countries (Austria, Belgium, Denmark, Estonia, Finland, France, Greece, Iceland, Italy, Netherlands, Norway, Sweden, Switzerland)

It is important to notice that the classification is based on the relative heterogeneity within the considered ECA area. For this reason "less concerned countries" still show an average obesity rate above 20% and overweight and obesity rates around 55%. In general, however, we find a separation which is clear enough to suggest differentiated interventions.

Table 3. Classification of ECA countries based on the triple dimension of malnutrition (output from Cluster Analysis)

	Cluster analysis				
	1	2	3	4	Total
Number of countries	6	13	18	13	50
Overnutrition component	-2.04	-0.06	0.63	-0.35	0.00
Undernutrition component	1.76	1.83	-0.19	-0.44	0.00
Micronutrient deficiencies component	1.67	1.53	0.06	-0.76	0.00
	Original indicators				
% Obese	14.72	22.95	25.68	20.71	22.78
% Obese (Female)	18.34	29.20	27.03	20.56	24.05
% Overweight and obese	42.08	55.15	59.58	54.57	55.95
% Overweight and obese (Female)	43.70	58.80	56.08	49.51	52.72
% Undernourished 2011	10.84	14.85	<5.00	<5.00	5.98
% Undernourished 2000	16.88	18.10	<5.00	<5.00	7.05
% Stunted children under 5	22.65	19.90	7.86	5.46	9.00
Calorie adequacy	113.00	123.00	129.00	136.00	130.00
% Pre-school age children with anaemia	40.40	36.20	24.17	12.63	22.35
% Pregnant women with anaemia	39.78	40.00	26.25	15.72	24.57
% Non-pregnant women with anaemia	42.94	31.45	20.30	13.96	20.86
% Pre-school age children with vitamin A deficiency	31.96	31.50	11.52	2.87	11.42
% Population at risk of inadequate intake of zinc	32.00	47.40	16.60	9.44	16.95
Cluster label	*Undernutrition*	*Triple burden*	*Overnutrition*	*Less concerned*	
	SOFA 2013 classification: correspondences				
Stunting, micronutrient deficiencies	4	1	0	1	6
Stunting, micronutrient deficiencies and obesity	2	11	7	0	20
Obesity	0	1	11	1	13
No malnutrition problem	0	0	0	11	11
Total	6	13	18	13	50

4.2. Heterogeneity in socio-economic drivers

A differentiated approach can be strengthened by looking at differences in the range of potential explanatory factors and drivers. First, PCA was applied to three sets of variables measuring socio-demographic characteristics, some indicators on food markets (price and trade), and economic determinants, respectively. Results from the PCA are summarised in Table 4, which also suggest an interpretation for those components which were retained. The two components from indicators related to social, political and demographic factors measure the level of political stability and income equality. They are distinguished, as the first emphasises aspects like the ratio of public expenditure on total health expenditure, urbanisation, but also life expectancy (and ageing) and net immigration, while the second places a high weight to female participation to the labour force. The two components extracted from the small set of indicators referring to food markets are neatly defined, one covers the relevance of net food imports and dependency from cereal imports, the second is associated with the level of food prices and their volatility.

Finally, three economic components are identified. The first one is inversely associated with incomes (as measured by real GDP in power-purchasing parity terms), and positively associated with the relevance of agricultural value added and employment in the economy. The second component has a strong association with the relevance of natural resources for the national economy, and is inversely related to the value added for the service sector. The first two components have also a positive association with economic growth. The third component is also inversely associated with GDP, while a major positive association emerges with foreign direct investments. Thus, the first and third components represent indicators of economic delay, while the second singles out the relevance of economic resources. While this interpretation is subjective, it does not affect the analysis of differences across clusters, which are also explored through the original indicators as shown in Table 5.

The last column of Table 5 reports the results from an one-way ANOVA test. The magnitude of the F-statistic represent a standardised indicator of the strength of heterogeneity between clusters for each component or variable. Thus, the first social dimension is the most relevant discriminating factor across the four group. As a matter of fact, all the original variables (political stability, income equality, the proportion of public health expenditure, urbanisation, life expectancy and ageing) show high and significant values. Furthermore, a linear connection seem to emerge between these variables and the classification. As stability, equality and social welfare increase, countries seem to evolve across the various stage of the nutrition transition, from undernourishment, to the multiple burden of malnutrition, hence to overnutrition only and finally to malnutrition relatively under control. Consistently with this finding, the second factor in terms of relevance corresponds to the first economic component, and again the correspondence is linear and consistent across the original indicators. The nutrition transition is associated linearly with higher incomes and a transformation from an agriculture-based to a service-based economy. The inverse relationship between the transition stages and economic growth (real GDP growth) seems to suggest that the situation is dynamic and the economic transition is still in progress.

Table 4. Principal component analysis on social, demographic and economic factors: loadings

	Component		
	1	2	3
Social and demographic factors			
POLSTAB	.69	.47	
LIFETOT	.86		
AGEING	.80		
URBAN	.79		
GINI	-.46	-.61	
LABFEM		.77	
UNEM		-.77	
IMMIG	.73		
HEALTHEXPPUB	.80		
% of variance explained (cumulative)	48%	64%	
1. Social welfare, equality and urbanisation (SOCIAL)			
2. Social, economic, and gender equality, female labour participation (EQUAL)			
Food market forces			
FOODIMP		.85	
CERIMPDEP		.80	
PRICE	.88		
PRICEVOL	.82		
% of variance explained (cumulative)	42%	77%	
1. Relevance of food imports (IMPORT)			
2. Level of prices and volatility (PRICES)			
Economic factors			
VADDAG	.77		
VADDSER	-.42	-.82	
EMPLAG	.91		
EMPLSER	-.92		
FDI			.98
GDP	-.76		-.49
NATRES		.95	
GDPCHG	.60	.67	
% of variance explained (cumulative)	42%	69%	85%
1. Economic development delay and relevance of agriculture (ECONDELAY)			
2. Relevance of natural resources and economic growth (NATURALRES)			
3. Economic development delay and relevance of FDI (DELAYFDI)			

Note: component loadings after VARIMAX rotation. Components with an eigenvalue larger than 1 were retained.

In terms of the other components, it is worth noting a few aspects. First, those countries which are still subject to a high burden from undernourishment and micro-nutrient deficiencies are also those whose economies are highly dependent on natural resources. Second, even if the price component does not emerge as particularly relevant, the original indicator on food prices is a major discriminant force. In relative terms, food prices seem to play a major role in those countries were the undernutrition and micro-nutrient components has high values. Also interesting is the high value of dependency from food imports (cereals in particular) in the ‘undernutrition’ cluster, which is combined with a high relevance of agriculture. This could suggest that development in agricultural technology and productivity is an important trigger for the economic and nutrition transition, once more calling for agricultural policies to be targeted and co-ordinated with other economic instruments.

Table 5. Differences in social, demographic, and economic driving forces across the four clusters

	Cluster 1 Undernut	Cluster 2 Triple burden	Cluster 3 Overnut	Cluster 4 Less Conc	Total	F-statistic	
Principal components							
SOCIAL	-1.98	-0.42	0.36	0.84	.00	48.60	**
EQUAL	0.27	-0.43	-0.16	0.53	.00	2.53	
IMPORT	0.82	0.41	-0.03	-0.75	.00	5.89	**
PRICES	0.32	0.41	-0.30	-0.15	.00	1.60	
ECONDELAY	0.91	0.86	-0.33	-0.82	.00	16.46	**
NATURALRES	1.53	-0.15	-0.17	-0.32	.00	7.58	**
DELAYFDI	0.08	0.12	-0.19	0.10	.00	0.32	
Original indicators							
GDP per capita, PPP (constant 2005 international $)	4587	10231	24399	32229	20374	18.64	**
GINI Index	7.0	4.4	2.7	1.1	3.2	13.48	**
GDP Growth (yearly rate, 2000-2010)	36.7	32.3	31.7	28.0	31.5	5.42	**
Unemployment, total (% of total labor force)	10.4	14.8	10.8	8.0	11.0	2.59	
Labor participation rate, female (% of female population ages 15+)	53.9	48.9	49.6	55.2	51.4	2.09	
Index of Political Stability and Absence of Violence	-.60	.03	.42	.90	.32	10.02	**
Life expectancy at birth, total (years)	68.9	73.8	77.1	80.4	76.1	20.86	**
Health expenditure, public (% of total health expenditure)	39.6	59.0	71.2	77.2	65.8	19.13	**
Population ages 65 and above (% of total)	6.2	12.9	14.5	16.8	13.7	17.18	**
Urban population (% of total)	42.1	58.8	71.5	79.5	66.7	20.49	**
Net migration	-182898	-59426	322853	296614	155948	3.25	*
Agriculture, value added (% of GDP)	14.8	9.4	3.2	2.4	6.0	20.11	**
Industry, value added (% of GDP)	37.0	27.5	28.9	26.0	28.7	2.32	
Services, etc., value added (% of GDP)	48.2	63.1	67.9	71.7	65.3	10.65	**
Employment in agriculture (% of total employment)	41.9	22.0	6.5	4.0	12.5	25.91	**
Employment in industry (% of total employment)	14.8	24.6	27.1	22.7	24.3	4.49	**
Employment in services (% of total employment)	43.4	53.3	65.9	71.9	62.6	15.53	**
Total natural resources rents (% of GDP)	21.8	4.1	1.7	1.6	4.7	9.39	**
Foreign direct investment, net inflows (% of GDP)	7.2	4.8	-6.3	2.5	0.5	0.80	
Value of food imports over total merchandise exports	22.7	26.9	7.2	7.2	14.2	6.62	**
Cereals Imports dependency ratio	34.2	31.0	35.8	46.4	37.1	0.48	
Food Price Level Index	1.9	1.5	1.3	1.1	1.4	13.72	**
Domestic Food Price Level Index Volatility	55.0	31.4	36.3	22.9	32.5	1.09	

Note: **significant at the 99% confidence level; *significant at the 95% confidence level

The last column of table 5 reports the results from an one-way ANOVA test. The magnitude of the F-statistic represent a standardised indicator of the strength of heterogeneity between clusters for each component or variable. Thus, the first social dimension is the most relevant discriminating factor across the four group. As a matter of fact, all the original variables (political stability, income equality, the proportion of public health expenditure, urbanisation, life expectancy and ageing) show high and significant values. Furthermore, a linear connection seem to emerge between these variables and the classification. As stability, equality and social welfare increase, countries seem to evolve across the various stage of the nutrition transition, from undernourishment, to the multiple burden of malnutrition, hence to overnutrition only and finally to malnutrition relatively under control. Consistently with this finding, the second factor in terms of relevance corresponds to the first economic component, and again the correspondence is linear and consistent across the original indicators. The nutrition transition is associated linearly with higher incomes and a transformation from an agriculture-based to a service-based economy. The inverse relationship between the transition stages and economic growth (real GDP growth) seems to suggest that the situation is dynamic and the economic transition is still in progress.

In terms of the other components, it is worth noting a few aspects. First, those countries which are still subject to a high burden from undernourishment and micro-nutrient deficiencies are also those whose economies are highly dependent on natural resources. Second, even if the price component does not emerge as particularly relevant, the original indicator on food prices is a major discriminant force. In relative terms, food prices seem to play a major role in those countries were the undernutrition and micro-nutrient components has high values. Also interesting is the high value of dependency from food imports (cereals in particular) in the ‘undernutrition’ cluster, which is combined with a high relevance of agriculture. This could suggest that development in agricultural technology and productivity is an important trigger for the economic and nutrition transition, once more calling for agricultural policies to be targeted and co-ordinated with other economic instruments.

4.3. The burden of malnutrition

Based on estimates of DALYs from the IHME Global Burden of Diseases data, we can further explore the triple burden of malnutrition across the three clusters. Table 6 reports mean DALYs, together with two indicators on health expenditure.

Table 6. Burden of malnutrition in ECA countries

Variable	*Undernutrition*	*Triple burden*	*Overnutrition*	*Less concerned*	*Total ECA*
Lost DALYs by risk factor (DALYs per 100,000 population)					
TOTAL DALYs lost to disease	33925	38996	33156	26912	32574
Child and maternal undernutrition	2174	471	294	48	384
Childhood underweight	*298*	*22*	*8*	*2*	*27*
Suboptimal breastfeeding	*1033*	*74*	*20*	*0*	*88*
Micronutrient deficiencies[a]	*843*	*375*	*266*	*46*	*268*
High BMI	2535	4452	3788	2186	3431
Dietary risk factors	5602	9515	6236	3304	5972
High blood pressure	4256	8425	5092	2573	4916
High Total Cholesterol	899	2390	1877	886	1657
Alcohol use	1582	5425	4161	1095	3465
Tobacco smoking	2769	5089	4251	2793	3936
Yearly % change in dalys lost to risk factors, 1990-2010					

Total disease	-1.4	0.2	-0.4	-0.4	-0.4
Child and maternal undernutrition	-5.7	-2.9	-4.0	-0.5	-4.3
High Body Mass Index	1.6	1.5	0.8	0.0	0.8
Micronutrient deficiencies[a]	-0.4	-1.1	-0.7	-0.4	-0.7
Dietary risk factors	0.4	0.9	-0.5	-1.6	-0.4
Life expectancy and health expenditure					
Life expectancy at birth	68.5	71.9	75.4	81.2	75.8
Change in life expectancy (total years gained)	2.6	1.5	4.2	4.6	3.8
Health expenditure per capita, PPP (2005 international $)	252	730	2257	3817	2275
Health expenditure, public (% of total health expenditure)	41.8	61.8	70.8	77.0	69.1
Yearly % change in real per capita health expenditure	8.8	8.0	6.5	5.1	6.0
% change in health expenditure per year of life expectancy gained	98.6	144.0	37.3	24.0	36.4

Source: our processing of GBD 2010 data

Note: weighted averages using country populations as weights

[a] The GBD 2010 data-set does not include an aggregate estimate for micronutrient deficiencies. Our estimate is the simple difference between total DALYs lost to child and maternal undernutrition and DALYs lost to childhood underweight and suboptimal breastfeeding. This figure may be an underestimate of the actual burden, because childhood underweight and suboptimal breastfeeding are likely to be associated with micronutrient deficiencies.

From Table 6, two pieces of information emerge as dominant. First, an exploration of the relation between the burdens of malnutrition and the associated DALYs needs to take into account other aspects than the mere malnutrition statistics, and especially life expectancy and the age structure of the population. Second, the relationship between malnutrition, its burden, and health expenditure is obviously endogenous. While malnutrition generates a social and economic burden, including higher health expenditure, the level of health expenditure – associated with resource availability – also acts in mitigating the burden of disease. Thus, simple descriptive statistics are not sufficient to provide an even rough quantification of the complex relationship between nutrition outcomes, their drivers, and the burden they generate.

5. Closing remarks

This paper provides the background information on the available macro-data and the statistical techniques employed to provide quantitative support to a policy analysis study in the ECA Region. While the available data is quite heterogeneous in terms of quality and is affected by gaps and inconsistencies, we show that a careful work of harmonization accompanied by the application of multivariate data summarisation techniques such as Principal Component Analysis and Cluster Analysis does provide a very informative picture on the malnutrition situation in the region.

We find that the optimal classification of ECA countries in terms of their malnutrition situation, and considering all three burdens of malnutrition, consists in four groups of countries. The fifty countries in the ECA regions are subdivided into four groups, relative to the ECA average: (1) those affected by undernutrition and micronutrient deficiencies but with relatively low overnutrition (6 countries); (2) countries affected by the triple burden of malnutrition, displaying persisting undernutrition, micronutrient deficiencies and significant levels of overnutrition (13 countries); (3)

countries mainly affected by overnutrition (18 countries) and (4) least affected countries with relatively few nutrition issues (13 countries). The distribution of malnutrition outcomes in the ECA region is strongly associated with indicators of social and economic development. Social inequalities and per capita income are especially relevant in explaining differences in the malnutrition burden; average yearly per-capita GDP (at purchasing power parity level) across the four "malnutrition groups" ranges between $ 4,500 in the poorest cluster and $32,000 in the wealthiest. We also link our country classification to DALYs lost to malnutrition, to obtain estimates of the social and economic burden which can be traced back to the various dimension of malnutrition. Further analysis is desirable to capture the endogenous links between malnutrition and economic development.

References

FAO (2013). The State Of Food And Agriculture 2013: Food Systems For Better Nutrition, Rome.

FAO REU (2012). Eastern Europe and Central Asia Agroindustry Development Country Brief. Tajikistan, FAO Regional Office for Europe and Central Asia (available at http://www.fao.org/fileadmin/user_upload/Europe/documents/Publications/AI_briefs/AI_breiefs 2012/fao_tajikistan.pdf).

Hotz, C. and Brown, K.H. (2004). Assessment of the risk of zinc deficiency in populations and options for its control. *Food & Nutrition Bulletin* 25(1).

Mazzocchi, M., Brasili, C., and Sandri, E. (2008). Trends in dietary patterns and compliance with World Health Organization recommendations: a cross-country analysis. *Public Health Nutrition* 11(5): 535-540.

Popkin, B.M. (2006). Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. *The American journal of clinical nutrition* 84(2): 289-298.

APPENDIX – Classification of ECA countries according to the Cluster Analysis and to SOFA 2013

Country	SOFA Grouping	Cluster analysis
Kyrgyzstan	1	1
Tajikistan	1	1
Turkmenistan	1	1
Uzbekistan	1	1
Azerbaijan	2	1
Georgia	2	1
Romania	1	2
Albania	2	2
Armenia	2	2
Bosnia and Herzegovina	2	2
Bulgaria	2	2
Croatia	2	2
Kazakhstan	2	2
Macedonia	2	2
Moldova	2	2
Montenegro	2	2
Serbia	2	2
Ukraine	2	2
Cyprus	3	2
Belarus	2	3
Latvia	2	3
Lithuania	2	3
Poland	2	3
Russian Federation	2	3
Slovakia	2	3
Turkey	2	3
Czech Republic	3	3
Germany	3	3
Hungary	3	3
Ireland	3	3
Israel	3	3
Luxembourg	3	3
Malta	3	3
Portugal	3	3
Slovenia	3	3
Spain	3	3
United Kingdom	3	3
Estonia	1	4
Iceland	3	4
Austria	4	4
Belgium	4	4
Denmark	4	4
Finland	4	4
France	4	4
Greece	4	4
Italy	4	4
Netherlands	4	4
Norway	4	4
Sweden	4	4
Switzerland	4	4