Assessing the impact of the Mediterranean-style diet in preventing non-communicable diseases

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Abstract

This paper explores the macroeconomic impact of the Mediterranean-style diet in reducing the risk of premature death from non-communicable diseases (NCDs). By utilizing an aggregate health production function approach, we investigate whether adopting the Mediterranean-style diet has a measurable country-level protective effect. Our analysis draws on data from 178 countries and develops two composite indexes to measure i) adherence to the Mediterranean-style diet and ii) the prevalence of metabolic syndrome. Our results show a departure from the Mediterranean-style diet in favor of the Western-style diet across countries in the Mediterranean region during the last decades. However, we find that adhering to the Mediterranean-style diet significantly reduces the prevalence of metabolic syndrome (after controlling for major potential confounding factors, such as health system performance and the implementation of WHO-recommended NCD prevention measures). The positive effects of the Mediterranean-style diet are, however, outweighed by the negative ones of unhealthy dietary patterns. These findings emphasize the need to reduce unhealthy food consumption by promoting a Mediterranean-style diet to prevent the health and economic burden of the leading NCDs.

Keywords: *Aggregate health production function, Mediterranean-style diet, Food consumption models, Non-communicable diseases, Preventable risk factors.*

1. Introduction

According to the World Health Organization (WHO), Non-Communicable Diseases (NCDs) are currently responsible for almost 74% of all deaths worldwide. The latest figures show that NCDs kill each year about 17 million people in the prime of their lives (i.e., between the ages of 30 and 69 years). Alarmingly, around four-fifths of these 'premature' deaths occur in low- and middle-income countries (WHO, 2023). The burden of such chronic diseases is mainly due to the four leading NCDs – that is, cardiovascular diseases, cancer, diabetes, and chronic respiratory diseases – which together account for over 80% of all premature NCD deaths globally (PAHO, 2020).

A large number of these premature NCD deaths, however, can be avoided by providing effective and equitable healthcare services – es-

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pecially early diagnosis and treatments – and by implementing primordial and primary prevention measures (WHO, 2013). Along with some non-modifiable risk factors (i.e., sex, age, and heredity), these chronic diseases share indeed a well-known set of key modifiable risk factors, namely, tobacco use, alcohol abuse, unhealthy diets and eating habits, physical inactivity, environmental pollution, and long-term psychological stress (WHO, 2014).

In other words, the rising prevalence of NCDs in both advanced and emerging economies is largely influenced by avoidable unhealthy lifestyle factors, with dietary habits playing a key role in prevention. A large amount of literature has consistently shown that unhealthy eating habits, such as regularly consuming ultra-processed foods – high in added sugars, unhealthy fats, sodium, and additives – processed meats and sugar-sweetened beverages, are major contributors to the global NCD epidemic (Lane *et al*., 2023). Conversely, research shows that embracing healthier diets, such as those based on the daily consumption of unprocessed and minimally processed home-prepared whole and plant-based foods, can significantly diminish the risk of developing one or more NCDs (Cerf, 2021). A crucial role in preventing NCDs through proper eating habits is played by the Mediterranean-style diet. This kind of diet, rich in fruits, vegetables, whole grains, lean proteins, and healthy fats, among the many benefits, can help in managing body weight, controlling cholesterol levels, and stabilizing blood sugar. More generally, by improving metabolic health, the Mediterranean diet reduces chronic inflammation, thus protecting against the onset of NCDs (Sánchez-Sánchez *et al*., 2020).

This paper investigates the impact of the Mediterranean-style diet in preventing NCDs from a macroeconomic perspective. Our primary focus is to answer the following research question: Does adopting the Mediterranean-style diet reduce the overall risk of premature death from NCDs at the country level? To deal with this issue, epidemiologists (Rothman *et al*., 2012) usually rely on the concepts of amenable mortality (i.e., deaths from causes that should not occur in the presence of effective medical care) and attributable fraction (i.e., the proportion of disease in a given population that can be attributed to a specific risk factor), (GBD, 2017; 2020). Instead, in economics, this question is typically framed within a health production function approach, where health is viewed as an output (i.e., a durable good) that people can produce starting with a set of medical and non-medical inputs (Auster *et al*., 1969; Grossman, 1972).

In the following pages, we use a health production function approach to determine if the Mediterranean-style diet has a measurable protective health impact at the macro level. So far, a relatively large number of studies have examined the impact of selected preventable (e.g., environmental, socio-economic, and behavioral) risk factors and various medical inputs on different types of health outcomes, such as life expectancy, mortality rates, quality or disability-adjusted life years, etc. (Maynard, 1983; Wagstaff, 1986; Thornton, 2010). To the best of our knowledge, however, our paper presents five main distinguishing features compared to prior empirical studies on the aggregate health production function.

First, we specifically address the role of the Mediterranean-style diet on the average overall risk of premature death from any of the four main NCDs. Second, we provide a country-level perspective using the most recent data available for 178 countries worldwide. Third, as explanatory variables, we develop two composite indexes to measure in each country: 1) the degree of adherence to the Mediterranean-style diet and 2) the prevalence of metabolic syndrome. Fourth, in order to control for the effects of potentially confounding variables, we also include in the quantitative analysis a robust metric of the performance of the national health systems, the so-called Healthcare Access and Quality Index (GBD, 2022). Fifth and finally, we take into account the country's progress in implementing the WHO set of 'best buys' interventions to prevent and control NCDs (WHO, 2022) to capture the impact of various public health measures on the risk of premature death from NCDs.

The remainder of the paper is structured as follows. Section 2 gives a brief overview of the main features of the Mediterranean-style diet

and its several health implications. Section 3 introduces some basic concepts of NCD epidemiology. Section 4 describes the data used and presents the model specifications. Section 5 discusses the main findings. Finally, Section 6 concludes with some implications for food policy and public health.

2. The Mediterranean-style diet: A pathway in preventing NCDs

The Mediterranean-style diet originates from the traditional culinary and eating habits of people living in countries such as Greece, Italy, and Spain. Over the last few decades, it has gained global recognition for its numerous health benefits. The Mediterranean-style diet (and its health impacts) have been extensively studied in the literature (Guasch-Ferré *et al*., 2021). This section provides just a brief overview of key concepts relevant to our purposes.

This diet focuses on plant-based foods, healthy fats, and lean proteins and is accompanied by a lifestyle that includes regular physical activity and social interactions. However, the Mediterranean-style diet is more than just a way of eating; it represents a holistic approach to life that emphasizes the pleasure of home-preparing and consuming meals based on fresh and minimally processed ingredients, following traditional culinary techniques. Its primary ingredients include whole grains and pulses, fresh vegetables and fruits, olive oil, nuts, and seeds. It is also based on a moderate consumption of dairy products (with cheese and yogurt preferred over butter and milk), and the use of blue fish and poultry instead of red meat. Wine, especially red wine, is regularly but moderately consumed, usually with meals. Herbs and spices are used to flavor food, reducing the need for salt (Dinu *et al*., 2017).

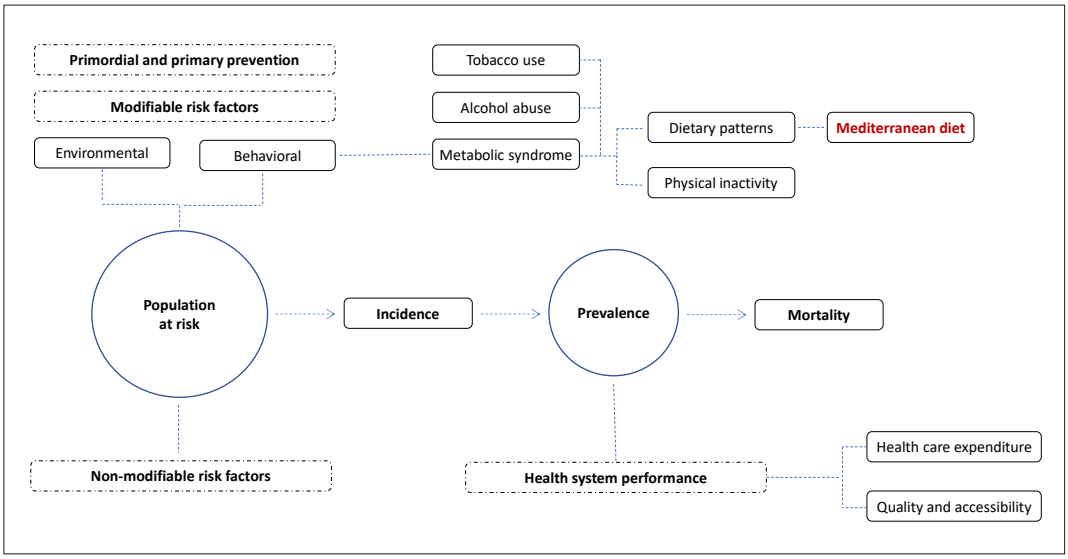
By avoiding industrial formulations and also limiting the consumption of processed foods from animal sources, the Mediterranean-style diet is widely recognized for its potential to prevent chronic diseases. For instance, numerous studies have demonstrated that lifelong adherence to this diet helps with weight management – this is why it is usually associated with a lower body mass index and reduced waist circumference – and significantly limits the risk of heart disease and stroke by helping reduce and increase cholesterol LDL and HDL, respectively. Moreover, being high in fiber and healthy fats, the Mediterranean-style diet not only promotes satiety and reduces overeating episodes but also helps lower blood pressure and improves insulin sensitivity, allowing cells to use blood sugar more effectively so as to lower the risk of developing type 2 diabetes. Finally, thanks to its anti-inflammatory foods, the Mediterranean-style diet has also been linked to a reduced risk of the onset of various types of cancers, including breast and colorectal cancer (an action mainly due to the high content of antioxidants and phytochemicals with anti-carcinogenic solid properties), (Gerber *et al*., 2015). Overall, the comprehensive health benefits of the Mediterranean-style diet are associated with a greater healthy life expectancy, as people who adhere to this diet in their lifetime tend to live longer and healthier (Martinez-Lacoba *et al*., 2018).

3. Some basic concepts of NCD epidemiology

The four leading NCDs have a multifaceted and complex origin. Figure 1 illustrates the interconnections among three fundamental concepts in NCD epidemiology: incidence, prevalence, and mortality. Incidence and mortality are flow variables, representing the number of new NCD cases and the number of NCD-related deaths occurring in a specific at-risk population over a defined period (e.g., one year). Prevalence is a stock variable, indicating the number of existing NCD cases in a specific population at a particular point in time (Porta, 2014).

These stock and flow relationships show that – other things being equal – the likelihood of premature death from any of the four leading NCDs is mainly influenced by two factors: 1) people's exposure to modifiable (avoidable) risk factors and 2) the provision of quality and equitable health care. On the one hand, exposure to risk factors impacts the number of new cases (incidence of NCDs) within a population at risk. On the other hand, access to effective healthcare determines the number of deaths (mortality due to

Figure 1 - The role of Mediterranean-style diet in preventing mortality from the leading NCDs.



NCDs) by affecting the patient's life expectancy (Bonita *et al*., 2006).

For our purposes, NCD modifiable risk factors can be broken down into environmental (e.g., air pollution, toxic chemicals, radiation, etc.) and behavioral risk factors (the so-called SNAP risk factors, that is, smoking, nutrition, alcohol, and physical activity). In turn, unhealthy nutrition and lack of physical activity usually result in a cluster of intermediate (metabolic) risk factors – such as raised blood glucose, raised blood pressure, overweight and obesity (particularly, excess body fat around the waist), and abnormal triglyceride and cholesterol levels – that underlies the metabolic syndrome, a condition significantly associated with an increased risk of developing one or more NCDs (Saklayen, 2018).

Finally, the health outcomes of those who live with one or more NCDs (i.e., the survival rates, and thus the mortality rates) crucially depend on three main factors: 1) the amount of resources allocated to the health system to tackle NCDs, 2) the allocative and productive efficiency of these resources, and 3) the effectiveness and fairness of the health services delivered. Given the existing stock of medical knowledge, the latter two factors can be summarized by the population's access to quality and equitable healthcare services (Bonita *et al*., 2006).

4. Methods

4.1. *Data*

Table 1 provides a short description of each variable used in this study, along with basic descriptive statistics. The WHO provides country data on the risk of dying prematurely from any of the four main NCDs (hereafter, *rdp*), defined as the age-adjusted percentage of 30-year-old-people who would die before their 70th birthday from these diseases, assuming that he or she would experience current mortality rates at every age and would not die from any other cause of death (WHO, 2019a). Hereafter, we use multivariate linear regression models with cross-sectional data from 178 countries worldwide to assess the impact of the Mediterranean-style diet on the country's average overall risk of dying prematurely from cardiovascular diseases, cancer, diabetes, and chronic respiratory diseases. To this aim, we collected data from several sources about the following explanatory variables.

The total country spending on healthcare goods and services, expressed as a percentage of GDP (hereafter, *hce*), was collected from the World Bank indicator database. This data is used as a proxy variable to account for differences in the amount of resources allocated to addressing NCDs (World Bank, 2022). The performance

Table 1 - Variables definitions and descriptive statistics.

Variable	*Definition*	*Mean*	*SD*	*Min.*	*Max.*	*n*
rdp	Probability of dying from any of CVD[1], cancer, diabetes, and CRD2 between age 30 and exact age 70, both sexes (%).	19.13	5.86	8.30	36.10	178
hce	Health expenditure as a percentage of GDP (%).	6.68	2.66	2.53	18.32	178
haq	Healthcare access and quality index (0 = min, 100 = max).	0.61	0.22	0.19	0.97	178
smoke	Prevalence of daily smoking, age-stand. rate, both sexes, person 18+ years.	17.76	8.38	3.30	42.60	177
drink	Prevalence of current drinkers, both sexes, person 15+ years.	39.68	23.01	0.38	92.20	178
obese	Prevalence of obesity (BMI[3] ≥ 30), age-stand. rate, both sexes, person 18+ years.	18.72	9.75	2.10	48.20	178
rbpre	Prevalence of raised blood pressure (SBP[4] ≥ 140 or DBP[5] ≥ 90), age-stand. rate, both sexes, person 18+ years.	24.51	4.57	11.00	33.40	178
rbglu	Prevalence of raised fasting blood glucose (≥ 7.0 mmol/L or on medication), age-stand. rate, both sexes, person 18+ years.	9.26	3.81	4.00	24.60	178
msi	Metabolic syndrome index: Composite index of *obese*, *rbglu* and *rbpre* (0 = min, 100 = max).	0.81	0.45	0.13	2.21	178
dietmed	Average calorie intake from plant-based foods (kcal/capita/day)[6].	1,361.25	363.94	459.00	2,373	178
dietwest	Average calorie intake from animal-derived foods plus sugars (kcal/capita/day)[7].	759.66	379.59	63.00	1,746.00	178
gdppc	Gross domestic product per capita (PPP, current international $, 2017).	18,912.13	19,435.01	766.59	113,365.18	178
A	Residual of estimated health production function (Equation 5, author calculation).	20.92	5.53	11.78	40.15	178
medit	Countries in the Mediterranean region (dummy variable)[8].					178
who	Country's achievements in implementing the WHO set of "best buy" interventions to prevent and control NCDs (dummy variable)[9].					178

Notes. [1] CVD = Cardiovascular diseases. [2] CRD = Chronic respiratory diseases. [3] Body mass index. [4] Systolic blood pressure. [5] Diastolic blood pressure. [6] Including cereals, pulse, vegetables, and fruits. [7] Including meat products, dairy products, eggs, and sugars. [8] 1 if the country is located in the Euro and Eastern Mediterranean region and 0 otherwise. [9] 1 if the country's achievements in implementing the WHO set of 'best buys' interventions to prevent and control NCDs reach at least a score of 3 out of 6 and 0 otherwise.

of national health systems was measured using the Healthcare Access and Quality Index (*haq*). This index, developed by Fullman *et al*. (2018), utilizes data from the Global Burden of Disease (GBD) study and is calculated on a scale from 0 to 100 (where higher scores indicate better access to quality healthcare). Specifically, for each country, the *haq* index measures healthcare quality and accessibility by evaluating the death rates from causes that could have been prevented through timely and effective medical care (also known as 'amenable mortality'). This evaluation offers insights into the effectiveness of healthcare systems across different regions or countries.

As outlined in Figure 1, in order to capture people's smoking and drinking behaviors as leading NCD risk factors, data on tobacco use and alcohol consumption were included in the study

Table 2 - Steps to calculate the Metabolic syndrome index (*msi*).

Indicator	*Minimum*	*Maximum*
Prevalence of obesity (*obese*)	1	50
Prevalence of raised blood pressure (*rbpre*)	10	35
Prevalence of raised fasting blood glucose (*rbglu*)	1	25
Example: Greece		
Actual values: Obesity = 24.90; Raised blood pressure = 19.10; Raised blood glucose = 6.60		
Dimension Index = (actual value – minimum value)/(maximum value – minimum value)		
Obesity = (24.90 – 1)/(50 – 1) = 0.49		
Raised blood pressure = (19.10 – 10)/(35 – 10) = 0.36		
Raised blood glucose = (6.60 – 1)/(25 – 1) = 0.23		
The *msi* index is the geometric mean of the dimensional indices of *obese*, *rbpre*, and *rbglu*:		
Metabolic syndrome index (*msi*) = $(0.49 \times 0.36 \times 0.23)^{1/3} = 0.35$		

by the country's age-adjusted prevalence rates of daily smoking (Ng *et al*., 2014; WHO, 2024) and current drinkers (WHO, 2019b), respectively. We denoted these two explanatory variables *smoke* and *drink*, respectively. The spread of the metabolic syndrome was measured by a composite index of the average country's prevalence rates of three fundamental NCD intermediate risk factors: 1) obesity, 2) raised blood pressure, and 3) raised blood glucose (again, all rates are age-standardized and hereafter denoted as *obese*, *rbpre*, and *rbglu*, respectively). The value of each of these variables was transformed into a corresponding normalized value according to the standard UN Development Programme methodology to compute the Human Development Index (UNDP, 2024). The geometric mean of the resulting three sub-indexes was thus used to compute a summary measure (denoted *msi*) of the country-level prevalence of the metabolic syndrome. All data required to compute *msi* were taken from the WHO Global Health Observatory data repository (WHO, 2019a). Table 2 summarizes the methodology and goalposts (i.e., each metric's maximum and minimum limits) applied to compute the composite index *msi*.

Despite the challenges of summarizing in a single variable a complex phenomenon such as the Mediterranean-style diet, we follow the current literature in measuring the adherence to the Mediterranean diet by computing – from the FAO Balance foods sheets (FAO, 2024) – the daily consumption of per capita calories derived from two kinds of foods. On the one hand, plant-based foods and fish (i.e., whole cereals, pulses, vegetables, fresh and dried fruit, fishery products, and olive oil). On the other hand, foods from animal sources (i.e., meat, milk, cheese, eggs, and animal fats), plus margarine sugars and sugary drinks. (Alberti-Fidanza *et al*., 1999; Fidanza *et al*., 2004; Lepellere *et al*., 2019). These two new variables are measured in kcal/person/day and denoted *dietmed* and *dietwest*, respectively. We emphasize that *dietmed* and *dietwest* are merely raw proxy variables used here to capture a very complex phenomenon that is hard to synthesize in quantitative analysis.

Because the Mediterranean-style diet involves shared know-how about several interrelated environmental, technical, cultural, and social factors (Capurso, 2024), we also introduce a dummy variable (denoted *medit*) that assumes a value equal to 1 if the country is located in the Euro and Eastern Mediterranean regions and 0 otherwise. The list of countries included in these two regions, according to the WHO country classification, is collected in Table 1A in the Appendix. Furthermore, given the crucial role of prevention in tackling NCDs, in order to promote accountability in monitoring countries'

progress against NCDs, the WHO (2022) has defined a set of national progress indicators in the form of standardized questions, such as 'Has the Member State set time-bound national targets based on WHO guidance?'. Based on the results of the last NCD progress country monitor report (WHO, 2022), we assigned a score of 1, 0.5, and 0 according to the following level of achievement in six main indicators: 1 = fully achieved, 0.5 = partially achieved, and 0 = not achieved, respectively. This variable is labelled *who* and the complete list of indicators used in the paper is presented in Table 2A in the Appendix. Finally, we include the GDP per capita, measured in PPP international dollars from the World Bank open data repository (World Bank, 2022), to account for overall differences in living standards between countries.

4.2. *Model's specifications*

Health is a key component of human capital. Similarly to the accumulation of knowledge, achieving and maintaining a good health status requires an ongoing production process based on a combination of medical and non-medical inputs. In this context, health can be seen as a durable asset that provides life-long benefits (for a given set of hereditary factors). At a country level, an aggregate health production function – such as $H = f(M, NM)$, where H is some measure of the population's health conditions, and M and NM are vectors of medical and non-medical (i.e., social, economic, lifestyle, *etc*.) factors – summarize this concept by indicating the maximum amount of health that, *ceteris paribus*, can be generated in a given population from a specific set of inputs, given the state of medical knowledge and technologies (Grossman, 1972).

According to the stock and flow relationships briefly described in Figure 1, in order to assess the impact of health-related behaviors on the overall risk of dying prematurely from NCDs, one should regress the age-adjusted risk of dying prematurely (i.e., *rdp*) on a comprehensive measure of eating, drinking, smoking and others NCD health-related behaviors, by controlling for the main potential confounding factors (such as the amount of resources devoted to the health sector, the quality and accessibility of the health care delivered, the country's effort to tackle NCDs and so forth). However, developing a comprehensive measure of NCD health-related behaviors can be challenging, even from a conceptual standpoint. Furthermore, using a set of single indicators (i.e., one for each leading NCD risk factor) can invalidate the regression model. These indicators tend to be highly correlated (Ferretti, 2015), generating severe multicollinearity problems.

This is why we followed an approach similar to that used in growth theory to investigate the determinants of total factor productivity, or the so-called Solow's residual (Weil, 2016). Specifically, we carried out a three-step analysis that proceeded from the metabolic to the behavioral risk factors. First, we assessed the impact of the health system performance by estimating the following aggregate health production function:

$$(1) \quad rdp = A(hce^{\alpha} \times haq^{\beta}) \quad \rightarrow \quad \ln(rdp_i) = \ln(A) + \alpha\ln(hce_i) + \beta\ln(haq_i) + \varepsilon_i$$

where ln denotes the natural log of the variable of interest, and the subscript i refers to the i^{th} country. In Equation (1), the coefficients α and β measure the elasticity of *rdp* with respect to the country's health expenditure (*hce*) and the quality and fairness of the health care delivered (*haq*). Conversely, A can be interpreted as a sort of Solow's residual (i.e., it collects the portion of the risk of dying prematurely from NCDs that changes in *hce* and *haq* cannot adequately explain).

In estimating a standard aggregate production function (with labor and capital as inputs), differences in Solow's residual, which measures total factor productivity, can be attributed to disparities in human capital, technology, and institutions. Similarly, we hypothesize that NCD health-related behaviors are the fundamental determinants of A in the health production function described by Equation (1). As a second step, we, therefore, focus on non-medical causes of the risk of dying prematurely from NCDs. To investigate this, we computed the value of A for each country as $A = rdp/(hce^{\alpha} \times haq^{\beta})$, using the estimated coefficients α and β from Equation (1), along with the observed data on *rdp*, *hce*, and

haq. Given the set of country's data on *A*, we thus performed the following regression:

$$(2) \quad \ln(A_i) = \beta_0 + \beta_1 \ln(msi_i) + \beta_2 \ln(smoke_i) + \\ + \beta_3 who_i + \beta_4 medit + \varepsilon_i$$

to assess the role played by metabolic risk factors. In Equation (2), *msi* is the index of the prevalence of the metabolic syndrome (as computed in Table 2), *smoke* measures the prevalence rate of daily smoking, and *who* and *medit* are two dummy variables to control for the county's effort in preventing NCDs and its geographical location within the Euro and Eastern Mediterranean region. In other words, by estimating Equation (2) we test whether the prevalence of metabolic risk factors helps in understanding the variation in the risk of dying prematurely from NCDs that is not explained by variations in healthcare expenditures and the quality and accessibility of the healthcare delivered by the national health system, by controlling for a lading behavioral risk factor (i.e., smoking habits), the role of prevention measures (*who*), and the impact of the Mediterranean economic, natural and socio-cultural environment (*medit*).

Third, and finally, since our main focus is on the role of the Mediterranean-style diet as a protective factor in preventing NCDs, we investigate whether diet composition affects the prevalence of metabolic syndrome with the following equation:

$$(3) \quad \ln(msi_i) = \beta_0 + \beta_1 \ln(dietmed_i) + \\ + \beta_2 \ln(dietwest_i) + \beta_3 \ln(drink_i) + \\ + \beta_4 \ln(gdppc_i) + \beta_4 \ln(gdppc_i)^2 + \varepsilon_i$$

In Equation (3), eating and drinking habits are related to the metabolic syndrome index. Specifically, we tested the impact of our two measures of adherence to the Mediterranean-style diet (that is, *dietmed* and *dietwest*) and alcohol consumption (*drink*) on the spread of metabolic syndrome among the general population. Here, income per capita, as measured by the GDP per person (*gdppc*), is used as an explanatory variable to control for cross-country differences in the overall level of economic development. GDP per person is introduced in a quadratic specification to capture the empirical evidence that indicates non-linear Engel's curves for income and the consumption of several food categories, such as animal-sources foods (Cole & McCoskey, 2013; Kmetkova & Scasny, 2022). All equations were estimated in double-log form to directly measure the elasticity of the corresponding regressor on the dependent variable. Heteroskedasticity-consistent standard errors were used to control for heteroskedasticity (Huber-White-Hinkley (HC1) procedure in EViews 11) (IHS, 2020).

5. Results

5.1. *The decreasing adherence to the Mediterranean-style diet*

Despite its global recognition for its many health benef its, which greatly contributed to the region's historically high life (and healthy life) expectancy, the Mediterranean-style diet has declined in Mediterranean countries during the last decades. This ongoing shift in dietary patterns raises many concerns not only about public health but also about the preservation of cultural traditions and the sustainability of agro-food systems (Dernini *et al*., 2013). The long-term declining trend is illustrated in Figure 2, which displays the changes in the ratio between the variables *dietmed* and *dietwest* from the early sixties to the present day in the Mediterranean region in comparison to Northern Europe and the Americas. Although this ratio can be used only as a proxy variable for measuring adherence to the Mediterranean-style diet, data show a one-third decrease in the *dietmed*/*dietwest* ratio for countries included in the Mediterranean region (the red line, labeled *medit*), similar to what happened in South American countries. Conversely, the ratio has steadily increased in Northern European and American countries, thus reducing their gap with the Mediterranean countries.

Figures 3 and 4 provide an explanation for this decline of the Mediterranean-style diet in its own areas of origin and first diffusion. Except for Eastern European countries, starting from the 1960s, there has been an increasing worldwide trend in the average calorie intake from plant-based sources (Figures 3*a* and 3*b*).

However, as illustrated in Figures 4*a* and 4*b*,

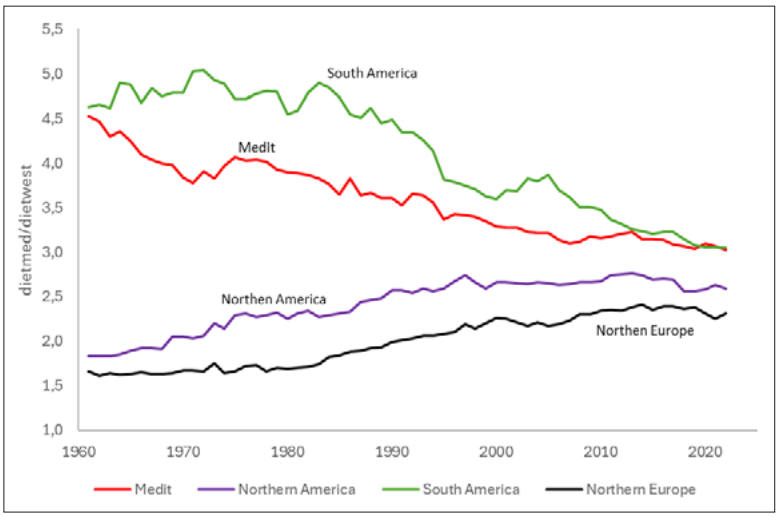


Figure 2 - The ratio between daily calorie intake from plant- and animal-based foods (*dietmed*/*dietwest*).

the Mediterranean region is among the areas where the consumption of animal-based foods has increased the most. Whereas in many other areas (such as other European regions and North America), the consumption of animal-sourced products has remained nearly constant, in the Mediterranean countries it has more than doubled, from 400 to 900 kcal/person/day. This sharp increase overcame the growth that occurred in the consumption of food derived from fruits and vegetables (which during the same time period increased by around 55%), resulting in a changed food landscape for the Mediterranean countries.

There are several reasons for this decreasing adherence to the Mediterranean-style diet. One major factor is the growing globalization and urbanization of Mediterranean societies. The spread of multinational fast food chains and ultra-processed foods and drinks implies that more convenient but less nutritious alternatives are currently replacing traditional meals. Busy lifestyles and the increase of dual-income households leave less time for cooking fresh, wholesome meals, leading to a greater reliance on quick, processed foods that do not align with the core principles of the Mediterranean-style diet (Godos, 2023).

Some of these complex phenomena are partially captured in Figure 5, where the average yearly consumption of ultra-processed foods and drinks – estimated by Vandevijvere *et al*. (2019) and measured in total kg/person/year – is plotted against the ratio between *dietmed* and *dietwest*, following the WHO world countries classification in six main geographic regions, plus our own created *medit* region. The graph indicates that a lower *dietmed*/*dietwest* ratio is linked to higher consumption of ultra-processed foods and drinks (*upfd*). Countries in the Mediterranean region (represented by the red dots) and those in other world areas seem to follow the same trend, although the phenomenon is more marked in developing countries, such as those included in the African region (the light-blue rectangles).

Complex economic structural changes also influence the evolution of dietary patterns. Data in Figure 6 illustrate an Engel's curve for the adherence to the Mediterranean-style diet (as measured by the ratio between *dietmed* and *dietwest*) and the level of economic development (as measured by the GDP per capita). As income rises, countries tend to shift toward a diet based mainly on animal-source foods. For countries within the Mediterranean region, a ten percent increase in per capita GDP decreases the *dietmed*/*dietwest* ratio by 6.5%. However, prices also play a role as economic factors that encourage changes in diet. Fresh, high-quality ingredients like olive oil, fish, and organic vegetables, central to the Mediterranean-style diet, have become more expensive in many Mediterranean countries. Fam-

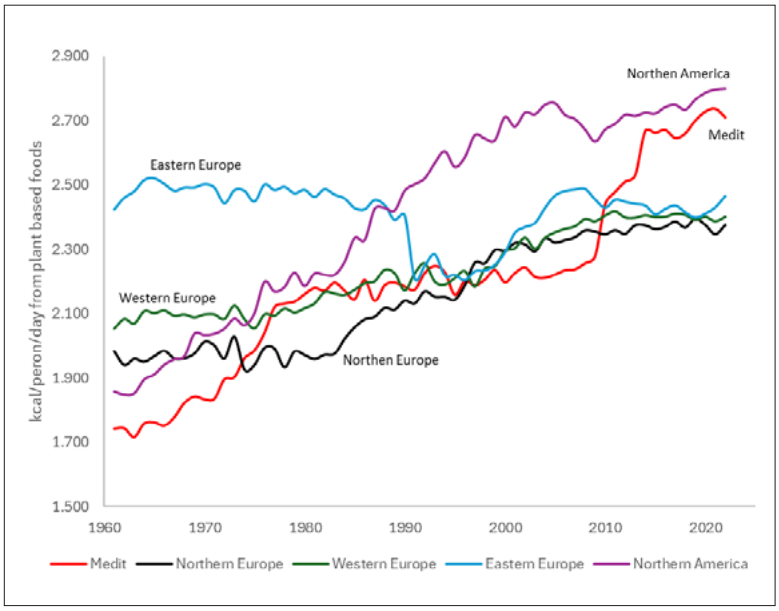


Figure 3a - Evolution of daily calorie intake from plant-based foods.

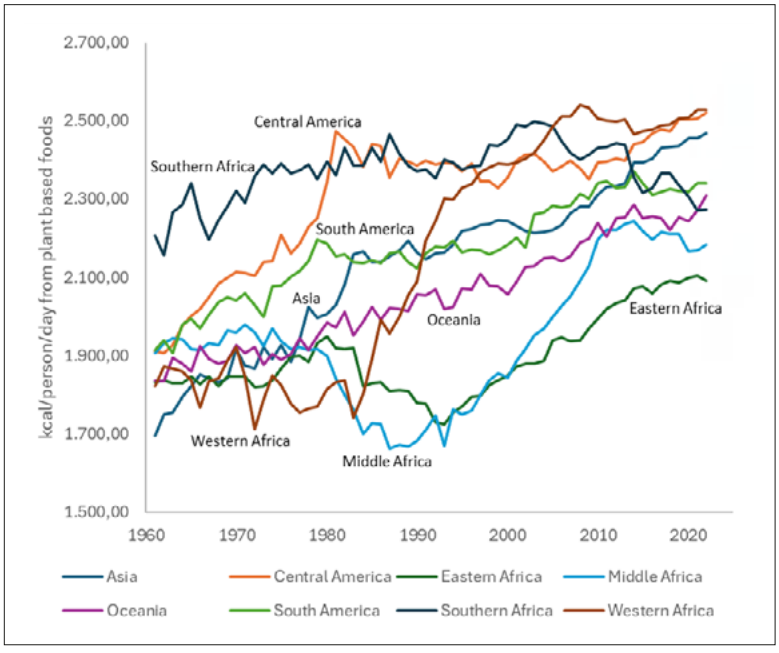


Figure 3b - Evolution of daily calorie intake from plant-based foods (world regions).

ilies may opt for cheaper, less healthy food options in times of economic hardship, prioritizing affordability over nutritional value. This trend can also be exacerbated by economic crises in countries such as Greece and Italy, where the cost of living has risen sharply, making it harder for people to maintain a diet rich in fresh but expensive local products (Colaprico *et al*., 2019).

Moreover, cultural shifts and evolving tastes, particularly among younger generations, have contributed to the decline of the Mediterranean-style diet. As adolescents and young adults in Mediterranean countries are increasingly exposed to global food trends – promoted and

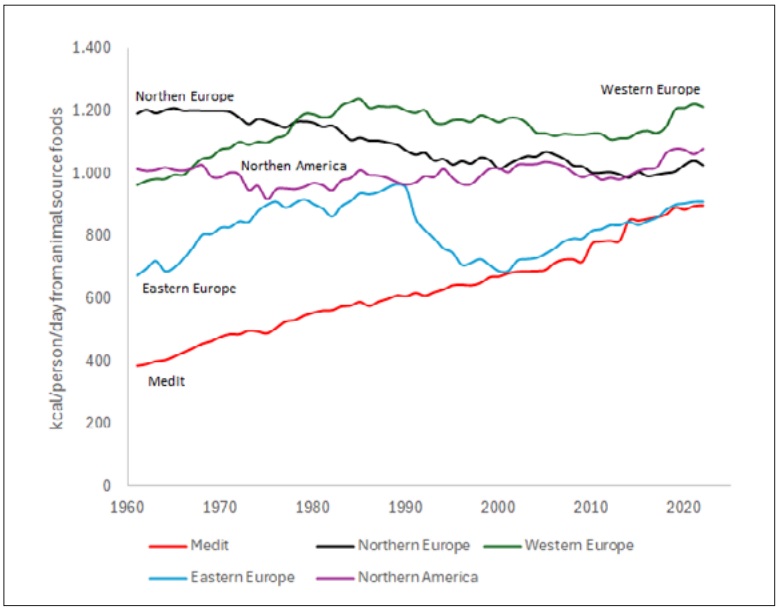


Figure 4a - Evolution of daily calorie intake from animal-based foods.

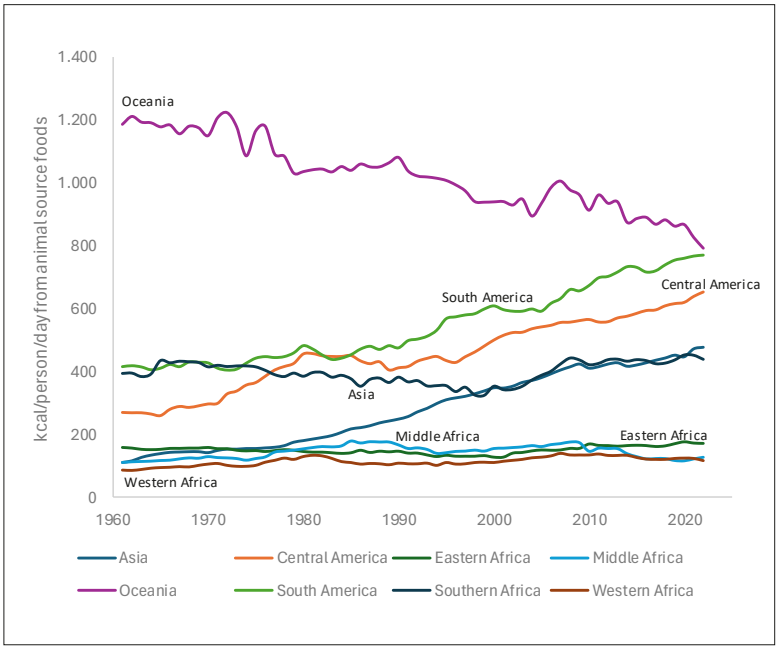


Figure 4b - Evolution of daily calorie intake from animal-based foods (world regions).

highly marketed by world-leading multinational food corporations – their diets tend to shift toward industrial processed food and beverages. This transition not only results in adverse health effects but also diminishes the region's cultural and culinary heritage, as traditional Mediterranean dishes are being prepared and consumed less frequently. Reversing this trend may require a mix of public health initiatives, educational campaigns, and policies that support access to fresh, locally sourced foods while preserving the long-standing Mediterranean culinary traditions that have contributed to the health and well-being of these populations (Vilarnau, 2019).

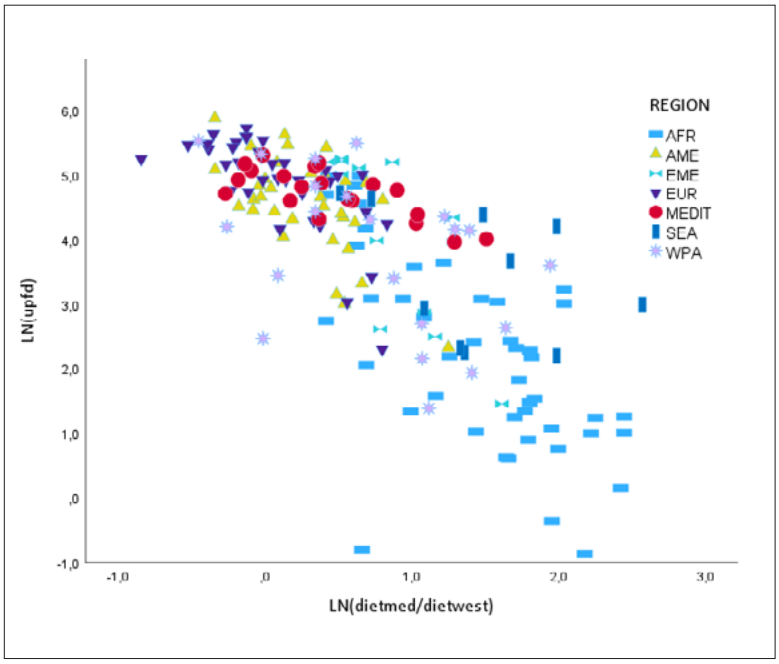
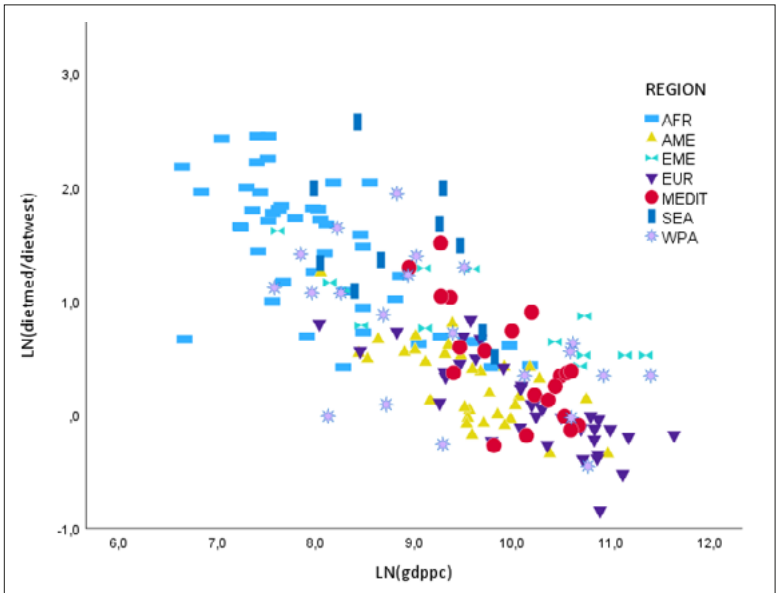


Figure 5 - Relationship between the adherence to the Mediterranean diet (as measured by the *dietmed/dietwest* ratio) and the consumption of ultra-processed foods and drinks.



Note. WHO regions: Africa (AFR), Americas (AME), Euro Mediterranean, except Medit (EME), Europe, except Medit (EUR), South-East Asia (SEA), and Western Pacific (WPA).

Regression result: Ln(dietmed/dietwest) = 6.97 – 0.65Ln(gdppc)

(0.15)

N = 20 $R^2 = 0.50$ t = -4.27

Estimated error in parentheses.

Figure 6 - Economic development (GDP per capita) and the *dietmed/dietwest* ratio.

Table 3 - OLS regression results.

Eq. 1), dependent variable: ln(*rdp*)			
rdp is the probability of dying between ages 30 and 70 years from any of the four main NCDs			
Independent variables		Coefficient	Std. Error[1]
Health expenditure as a share of GDP	*ln*(*hce*)	-0.198***	0.045
Healthcare access and quality index	*ln*(*haq*)	-0.431***	0.049
Constant		3.011	0.103
Adjusted *R*-squared = 0.42			
No. of observations = 178			
Eq. 2), dependent variable: ln(*A*)			
A is the residual of the estimated health production function (Eq. 1)			
Independent variables		Coefficient	Std. Error[1]
Metabolic syndrome index	ln(*msi*)	0.385***	0.047
Prevalence of daily smoking	ln(*smoke*)	0.161***	0.027
Country's achievements in preventing NCDs	who	-0.131***	0.030
Countries in the Mediterranean region	medit	-0.156***	0.043
Constant		3.040	0.080
Adjusted *R*-squared = 0.40			
No. of observations = 177			
Eq. 3), dependent variable: ln(*msi*)			
msi is the metabolic syndrome index			
Independent variables		Coefficient	Std. Error[1]
Average calorie intake from plant-based foods	ln(*dietmed*)	-0.245***	0.078
Average calorie intake from animal-derived foods plus sugars	ln(*dietwest*)	0.322***	0.052
Prevalence of current drinkers	ln(*drink*)	-0.145***	0.028
Gross domestic product per capita	ln(*gdppc*)	0.824***	0.304
Square of Gross domestic product per capita	ln(*gdppc*)^2	-0.048***	0.017
Constant		-4.222	1.307
Adjusted *R*-squared = 0.41			
No. of observations = 177			

*Notes: *** denote p < 0.001. [1] Huber-White-Hinkley (HC1) heteroskedasticity consistent standard errors.*

5.2. *Regression results*

The results from estimating Equations (1), (2), and (3) are presented in Table 3.

About Equation (1), the model explains about two-fourths of the cross-country variation in the risk of dying prematurely from any of the four main NCDs. This indicates that while the model is somewhat effective, a significant portion of the unexplained variation is probably due to the impact of behavioral risk factors. Both coefficients have the expected negative sign and are statistically significant at the 1% level. However, the elasticity of *haq* is nearly twice that of *hce*, indicating that increasing health spending can have a limited impact on people's health if these greater resources are not used to provide effective and equitable healthcare services. Our hypothesis about the determinants of the Solow residual in Equation (1) is corroborated by the results obtained from Equation (2). Again, all coefficients have the expected sign and are statistically significant at the 1% level. Specifically, differences in *A* – which measures variation in the age-adjusted risk of dying prematurely from any of the four main

NCDs not explained by variation in *hce* and *haq* – can be explained by differences in the prevalence of the metabolic syndrome (*msi*), country's effort in preventing NCDs, and the geographical collocation within the Euro and Eastern Mediterranean region, as measured by the dummy variables *who* and *medit*, respectively.

Finally, and more importantly, for our purposes, diet composition significantly affects the prevalence of metabolic syndrome. According to Equation (3), a 1% increase in the average daily intake of calories that characterizes the Mediterranean- and the Western-style diets (measured by the variables *dietmed* and *dietwest*) decreases and increases the prevalence of metabolic syndrome by 0.25% and 0.32%, respectively. The positive and negative signs of linear and squared GDP per capita support the idea of a sort of Kuznets curve for NCDs' eating-related behaviors, not captured by our proxy variables *dietmed* and *dietwest*. The idea is that as real income per capita increases, it initially tends to promote unhealthy eating and drinking habits until a certain income level is reached. Beyond this threshold, consumers start to prioritize healthier food choices (Ferretti, 2015). As in the previous equations, all coefficients are statistically significant at the 1% level, and the adjusted R^2 is around 0.40. Regarding the responsiveness of *msi*, one main finding is worth noting. The positive elasticity of *dietwest* is greater than the negative of *dietmed*. In other words, the Mediterranean-style diet does have a protective impact in preventing NCDs. However, the adverse effects of unhealthy eating habits overcome the positive ones, stressing the importance of avoiding the daily consumption of unhealthy foods, even in small amounts.

6. Discussion and conclusions

These findings corroborate the results of much previous work regarding the crucial role of eating patterns and, especially, of the Mediterranean-style diet as leading preventable risk factors to tackle NCDs (Zupo, 2023). From a policy perspective, this study supports the approach developed by the WHO (2014) in planning and implementing effective strategies to curb the current NCD epidemic (Budreviciute, 2020).

The regression results indicate the need to promote the Mediterranean-style diet. Unfortunately, today, the Mediterranean-style diet, as well as any other type of sustainable diet, is rarely practiced (defending it from the danger of "erosion" is the reason why the Mediterranean diet was recognized by UNESCO as an intangible heritage of humanity). It is not enough to inform and educate the consumer because, especially outside the home, they would not find the necessary conditions to practice the Mediterranean-style diet. The Food Environment[1] approach recognizes the fact that our food choices, and therefore the consequences of such choices, are strongly influenced by the contexts in which they are made. Therefore, it assumes that the most effective way to change the eating habits of individuals is to act on the structural elements that determine food choices. Obviously, strategic and political elements intervene above them. Promoting the Mediterranean-style diet requires a complex holistic strategy that intertwines public health policies, educational efforts, community initiatives, and effective partnerships across various sectors along the entire supply chain (and especially between agriculture and distribution). At the forefront, public health campaigns can be launched to raise awareness of the diet's benefits through media and the development of educational initiatives in key community locations (Bach-Faig *et al.*, 2011). Schools and workplaces play a crucial role, too, with healthy meal programs being introduced to both educate children and provide adults with better food choices by involving not only healthcare professionals but also farmers and local producers (Joubert & Szurek, 2012). Government policies are vital for ensuring that the Mediterranean-style diet is woven into na-

[1] According to the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (the United Nations body for assessing the science related to world food security and nutrition), the Food Environment is defined as the: "…physical, economic, political and sociocultural context in which consumers engage with the food system to make their decisions about acquiring, preparing and consuming food" (HLPE, 2017).

tional nutritional guidelines, with clear food labeling and subsidies encouraging the production and consumption of healthy foods (Dernini & Berry, 2015). However, this strategy should be centered on supporting local farmers by providing technological assistance and financial subsidies, improving market access to distribution, and organizing farmers' markets and direct sales platforms. Additionally, a strategy for promoting the Mediterranean-style diet effectively must include infrastructure investments and training programs in sustainable farming practices to support the foundation of local agriculture (European Commission, 2020; Capone *et al*., 2021).

This paper examined the macroeconomic impact of the Mediterranean-style diet in preventing NCDs, explicitly asking whether adopting the Mediterranean diet reduces the risk of premature death from NCDs at the country level. The findings can guide public health policies by highlighting the importance of implementing effective healthcare spending and prevention strategies for NCDs, such as promoting healthier dietary patterns, particularly in higher-income countries where Western diets tend to dominate. There are, however, limitations to this study that need to be acknowledged. First, the Mediterranean-style diet encompasses more than just eating patterns. It also includes each population's cultural and social features, which we attempted to capture with a simple dummy variable (e.g., *medit*). The regression output indicates that *medit* is statistically significant. However, this result does not allow us to understand the specific impact of each factor that makes up the complex societies of the Mediterranean regions. Second, to measure adherence to the Mediterranean-style diet, it is not sufficient to calculate the average calorie intake from different sources (i.e., plant or animal). This distinction, commonly made in the current literature, focuses solely on raw ingredients and fails to capture the significant role of the degree of food formulation and processing (i.e., it ignores the role of ultra-processed foods). Third, metabolic syndrome is a more complex phenomenon than our index (i.e., *msi*), as it also includes abnormal cholesterol or triglyceride levels and a measure of excess body fat around the waist (rather than increased BMI). Fourth, there is a missing variable concerning a measure of personal income distribution since an unequal income distribution plays a crucial role in determining the risk of dying from NCDs within each country. Fifth and finally, due to a lack of comprehensive data, we did not consider the role of fiscal policies, such as taxes and subsidies, on food production and consumption. Further research should be carried out to overcome these critical limitations of our work.

Abbreviations

FAO: Food and Agriculture Organization of the United Nations.
GFRP: Global Food Research Program.
HLPE: High-Level Panel of Experts on Food Security and Nutrition.
MSD: Mediterranean-Style Diet.
NCDs: Non-Communicable Diseases.
PAHO: Pan American Health Organization.
PEN: Pan-European Policy Evaluation Network.
UNDP: United Nations Development Programme.
UPFs: Ultra-processed foods.
WHO: World Health Organization.

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Appendix

Table 1A - List of countries in the Mediterranean region.

HDIG	*WBIG*	*Country*
H	UMI	Albania
H	UMI	Algeria
H	UMI	Bosnia and Herzegovina
VH	HI	Croatia
VH	HI	Cyprus
M	LMI	Egypt
VH	HI	France
VH	HI	Greece
VH	HI	Israel
VH	HI	Italy
H	UMI	Lebanon
H	UMI	Libya
VH	HI	Malta
VH	UMI	Montenegro
M	LMI	Morocco
VH	HI	Portugal
VH	HI	Slovenia
VH	HI	Spain
H	LMI	Tunisia
H	UMI	Turkey

Notes:
HDIG, Human Development Index group (VH = very high, H = High, M = Medium HDI group)
WBIG, The World Bank income group (HI = High, UMI = Upper-middle, LMI = Lower-middle income group.

Table 2A - WHO progress monitoring indicators used to compute the dummy variable.

1. National NCD targets: "Member State has set time-bound national targets based on WHO guidance".
2. Risk factor surveys: "Member State has a STEPS survey or a comprehensive health examination survey every 5 years".
3. National integrated NCD policy/strategy/action plan: "Member State has an operational multisectoral national strategy/action plan that integrates the major NCDs and their shared risk factors".
4. Public education and awareness campaign on physical activity: "Member State has implemented at least one recent national public awareness and motivational communication for physical activity, including mass media campaigns for physical activity behavioural change".
5. Guidelines for management of cancer, CVD, diabetes and CRD: "Member State has evidence-based national guidelines/protocols/standards for the management of major NCDs through a primary care approach, recognized/approved by government or competent authorities".
6. Drug therapy/counselling to prevent heart attacks and strokes: "Member State has provision of drug therapy, including glycaemic control, and counselling for eligible persons at high risk to prevent heart attacks and strokes, with emphasis on the primary care level".