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The Net Effect of Wealth on Health for Non-Communicable Diseases

Alicja Olejnik,

Agata Żółtaszek

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FACULTY OF ECONOMICS AND SOCIOLOGY

University of LODZ

The Net Effect of Wealth on Health for Non-Communicable Diseases

Short running title: **Net Effect of Wealth on Health**

Alicja Olejnik

University of Lodz, Faculty of Economics and Sociology,
Department of Spatial Econometrics,
3/5 POW Street, 90-255 Łódź, Poland
ORCID ID: 0000-0002-8542-3250
alicja.olejnik@uni.lodz.pl

Agata Żółtaszek

University of Lodz, Faculty of Economics and Sociology,
Department of Spatial Econometrics,
3/5 POW Street, 90-255 Łódź, Poland
ORCID ID: 0000-0003-3657-288X
agata.zoltaszek@uni.lodz.pl
phone: +48 605 669 890
corresponding author

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Abstract

The wealth–health relationship is not unambiguous and constant. Indeed, a higher level of wealth affects individual and population health in two opposite ways. Increased risk factors raise the probability of some diseases especially non-communicable diseases (NCDs). Conversely, better healthcare and awareness reduce the chances of developing these diseases or raise the likelihood of treatment and cure. Therefore, the overall impact on health or the 'net effect' of wealth (positive or negative) may be challenging to determine. Moreover, this effect may not be fixed for different income groups. Thus, it states to reason that there may exist an 'affluence point' changing the predominant impact of wealth (positive/negative), which we will refer to as the 'health economic threshold'.

This paper aims to assess and quantify the hard-to-grasp overall impact of prosperity on the mortality of selected NCDs in European regions. In particular, we attempt to estimate both the net effect of affluence and the health economic threshold of GDP-mortality relationship, by developing a dedicated analytical tool. The original idea is based on joinpoint regression and forecasting methods. To our knowledge, no such study has been performed in health economics.

Our results show that in the case of most investigated diseases in more impoverished regions, mortality rises with prosperity. After crossing the health economic threshold of around 20 thousand euros per capita, the trend changes (it stabilises or reverses).

Keywords**:** health economics; health economic threshold; joinpoint regression; net effect of affluence; regional studies; non-communicable diseases (NCDs)

JEL: C50, C31, R11, I15, I18

1. Introduction

Diseases of affluence, ‘Western diseases’ or ‘21st-century diseases’ have been a major health risk for decades. These diseases have been widely recognised as the unexpected and undesirable consequences of socioeconomic development and wealth. A disease of affluence is considered an illness with higher prevalence, worse symptoms, or even mortality rates in more prosperous subpopulations (social groups, regions, households) than disadvantaged ones.

All serious health issues referred to as ‘Western diseases’ correspond to major premature deaths in developed regions. These ailments include a variety of cardiovascular diseases such as heart failure, stroke or coronary artery disease, respiratory system diseases (including asthma), neurological conditions (e.g., Parkinson’s and Alzheimer’s disease, dementia), obesity (as a disease and as a risk factor in many other illnesses), diabetes, mental problems (mostly frequent depression and anxiety) as well as substance and behavioural addictions, and finally cancers (World Health Organization [WHO] Report: ATLAS 2010…: 7-22, WHO Report: Global Report on Urban… 2016: 90-91, WHO Report: Global status… 2011: 1-160).

Some well-established relationships are seen between affluence and health (Vanitallie 2002: 40-45, Wolf et al. 2018: 5-85; WHO Factsheet for World… 2018, WHO Report: Improving mental health… 2019; WHO Factsheet: Mental health… 2019, Kim, et.al 2018: 75-85, Smeester et.al 2015: 107-121, WHO Report: Climate change… 2003: 10-164). Increasing environmental pollution, ubiquitous stress with modern lifestyle, unhealthy diet, insufficient physical activity, irregular sleeping patterns, and exposure to artificial light are by-products of modern life and socioeconomic development. These detrimental influences constitute risk factors impacting the prevalence of mental and neurological disorders, diabetes, cancer, and cardiovascular and respiratory illnesses (WHO Report: Global action plan… 2013: 2-101, WHO: Unknown author 2010: 1-2).

In recent years, there has been a growing interest in assessing the overall medical impact of socioeconomic conditions on the Western diseases’ prevalence. Economic research evaluating the association between wealth and health are still scarce and often contain conflicting findings (see Danaei et al. 2013, Farrell 2010, Labarthe 2011, Link 2007, Offer 2006). This ambiguity may indicate that the concept of the diseases of affluence itself may be partly misleading. Recent data and observations suggest that the relationship between economic development and prevalence is much more complex than previously expected. As previously indicated, harmful by-products of wealth negatively impact human health. However, the quality of healthcare and its accessibility are also determined by technological development and financial resources. This relationship means that more affluent regions and subpopulations are better prepared to prevent, diagnose, and treat illnesses. This advantage predominantly stems from better education of the general population, higher quality of healthcare specialists, more advanced medical technology financed through general taxes and common social or private medical insurance. Therefore, the wealth–health relationship is not explicit and constant and may be heterogeneous over the level of development.

As a result, WHO is changing the classification of illness and causes of death nomenclature to less biased categories: (1) infectious, parasitic, neonatal and nutritional issues, (2) non-communicable diseases (NCDs) and (3) injuries. The first group of diseases is still predominantly considered as diseases of poverty, posing the most significant threats in low-income countries and subpopulations. Injuries have a mostly random character and are related to occupational safety. The NCDs are currently the deadliest of these categories.

According to WHO Global Health Observatory, 71% of people die due to NCDs (up to 90% in some high-income countries), for a total of 57 million global deaths in 2016. This demonstrates that regardless of whether NCDs are considered 21st-century diseases, they are currently the leading cause of death and the most pressing healthcare challenge in most Western countries. Moreover, their health burden systematically increases in low- and middle-income countries (WHO Report: Noncommunicable…2017: 7-9, 16-209, WHO Report: Noncommunicable… 2018: 8-19, 28-221, WHO Report: Noncommunicable… 2020: 1-3, 10-203, Benson and Glasgow 2014: 175-184, WHO Report: Global action plan… 2013, WHO updated Appendix 3… 2017).

Overall, a higher level of wealth affects the individual and the population health in two opposite ways. Increased risk factors raise the probability of some NCDs, but better healthcare and awareness reduce the chances of developing these diseases or increase the likelihood of treatment and cure. Therefore, the overall impact on health or the ‘net effect‘ of wealth (positive or negative) may be challenging to determine. From now on, we will refer to that impact as the net effect of affluence, or net effect, for short. Moreover, this effect may not be fixed for different income groups. Thus, it states to reason that there may exist an affluence point changing the predominant impact of wealth (positive/negative) which we will refer to as the ‘health economic threshold‘.

Hence, this paper aims to assess and quantify the hard-to-grasp overall impact of prosperity on the mortality of selected NCDs in the European regions. In particular, we attempt to estimate both the net effect of affluence and the health economic threshold, using an econometric approach.

The paper is structured as follows. Section 2 offers a description of the incorporated data and basic distributional statistics. Section 3 presents our newly developed analytical instrument and some basics of exploratory spatial data analysis (ESDA). The results of the research and discussion are included in Section 4. The final section highlights the conclusions.

2. Data

To determine the overall effect of wealth on health in Europe, we include main categories of NCDs: diabetes mellitus, mental and behavioural disorders, diseases of the nervous system and the sense organs (neurological conditions), diseases of the circulatory system (cardiovascular diseases), diseases of the respiratory system, and neoplasms (cancers). The regional gross domestic product (GDP) per economically active population (at current market prices by Nomenclature of Territorial Units for Statistics 2 (NUTS 2) regions in purchasing power standard (PPS) euro) is a proxy of social, economic, and technological development. Among the few available data, this indicator seems to be the best reflection of the complex concept of regional affluence. Since the mortality is described by the age-standardised statistics, we also incorporate the GDP per economically active population (later referred to as GDP or GDP per capita) to eliminate the populations' age structure.

All the data used in the subsequent analysis is taken from the Eurostat Database. The data covers 282 regions of the European Union, plus Norway, Switzerland, the United Kingdom (UK) and Luxembourg. We use the mortality rate, defined as the number of deaths by cause of death per 100 thousand inhabitants, as the prevalence statistic. Since we aim to assess affluence's final or net effect, this statistic seems to be the most appropriate. Because the prevalence and mortality of NCDs depend on age, the analysis is based on age-standardised death rates (three-year average to account for the heterogeneous age structure of the European population; (Report of Eurostat… 2013). The most recent data available (15 February 2021) are 2013–2015 averages; thus, the fundamental analysis will be adjusted to that time frame. In particular, to preserve the causal relationship between affluence (measured by GDP) and prevalence (measured by mortality rates), we allow for a time lag. Therefore, the GDP values for the primary year (2013) are used.

Note that mortality rates are based on the information contained in the death certificates issued at the place of death rather than in the region of residence. There is no widely available data for the NCDs' and NUTS 2 areas on the number of ill or diagnosed people or NCDs' patients dying from other causes. Additionally, the number of deaths for regions with highly specialised clinics may be artificially inflated, distorting the analysis results in certain areas. Moreover, in some countries, data may not accurately reflect the actual situation due to differences in laws and procedures leading to an autopsy or the lack of it. This can lead, for instance, to overuse of the term 'cardiopulmonary failure' and consequently artificially increase the number of deaths caused by cardiovascular disease.

Basic statistics for included mortality rates for NCDs are presented in Table 1. It can be seen that, in general, the leading cause of death are cardiovascular diseases (over 400 deaths per 100 thousand of the population), and neoplasms are the second most common one (almost 270 per 100 thousand of the population). However, the highest diversity (measured by the relative standard deviation) can be observed for mental and behavioural disorders (63% of the mean value). The variation is relatively low for deaths due to cancer (12%).

Table 1. Basic statistics for three-year average (2013–2015), age-standardised death rates of selected NCDs (Europe, NUTS 2)

Disease	Mean	Std. dev.	Min	Max
Diabetes mellitus	21.96	11.02	5.13	69.18
Mental and behavioural disorders	41.72	26.16	0.19	101.61
Diseases of the nervous system and the sense organs	39.36	19.42	10.52	162.97
Diseases of the circulatory system	402.80	206.87	162.96	1225.61
Diseases of the respiratory system	85.53	30.58	31.56	174.34
Neoplasms	269.67	31.67	210.84	374.51

Source: Author's compilation

3. Methodology

The research is carried out in two stages. Firstly, we analyse the spatial distribution of NCDs mortality rates and their spatial patterns in association with the distribution of economic development using ESDA tools. Secondly, we attempt to quantify the net effect of prosperity on the mortality of selected diseases by developing a new, specially dedicated analytical tool based on an econometric approach and counterfactual analysis.

In this stage, we employed the idea of a joinpoint model to produce a specification that models a relationship between mortality levels of each disease and the level of development. Moreover, this specification is allowed to exhibit non-constant monotonicity, which might lead to assess the change point level of development at which the direction or strength of the relationship in question changes. If a change in monotonicity occurs, the point breaking the function can be interpreted as health economic threshold. The assessment of the individual patterns for each disease, together with extrapolation methods, enable the calculation of the numerical values of the net effects of affluence. This net effect is calculated for the respective region/country for each disease and is defined as the difference between the actual level of mortality and the hypothetical one – as if the region had a different level of affluence.

Regions do not constitute independent, isolated economies, but interact with each other. The mathematical description of the spatial structure can be represented by so called spatial weights matrix $\mathbf{W}=[w_{ij}]_{N\times N}$, where component w_{ij}, represents the relation between region *i* and *j*. Usually, this matrix is adopted a priori and has an exogenous character. The data are spatially autocorrelated when they tend to have similar values in neighbouring regions. Spatial autocorrelation can be studied at both local and global levels. The global spatial autocorrelation means the presence of spatial dependencies within, for example on average for all regions. The local spatial autocorrelation occurs when, for individual regions, we observe interactions with neighbours, but this is not a global trend. (Anselin 1988)

To investigate the regional dispersion and spatial patterns of mortality rates, we use local indicators of spatial association (LISA). Local Moran's I_i statistic allows evaluating a statistically significant relationship between a value at the *i*-th region and at the neighbouring ones

$$I_i = \frac{(z_i - \bar{z})}{\frac{1}{N}\sum_{j=1}^{N}\left(z_j - \bar{z}\right)^2}\sum_{j=1}^{N} w_{ij}\left(z_j - \bar{z}\right).$$

For the quantitative variable z, i and j represent regions, $\bar{z}$ describes the average of an investigated variable and w_{ij} are the elements of **W**. In subsequent analysis, the **W** matrix is based on queen contiguity spatial weight matrix, 1st order. (see Moran 1950, Anselin 1988, Olejnik and Olejnik 2020)

When a region with a high level of the phenomenon borders regions with similarly high values, high-high clusters (hotspots) emerge. Once low values are grouped with low values, low-low clusters (coldspots) form. There are also mixed groups: low-high, high-low. Only those locations for which local statistics are significantly different from zero are analysed.

The method which can be identified as a valuable tool for making inferences about changes in trends is a joinpoint regression, also known in a more general form as joinpoint regression or change-point regression. (see, for example, Sprent 1961, Sylwester 1965, Hinkley 1971, Yu et al. 2009, Lopez-Campos et al. 2014). Among other things, it is used both in the analysis of time changes in suicide rates (e.g., in Denmark, Dyvesether et al. 2018) as well as in the assessment of changing trends in the incidence of cancer (e.g., in Canada, Great Britain, Japan and Italy; see Jiang et al. 2010, Qiu et al. 2009, Crispo et al. 2013, Wilson et al. 2017). However, to our knowledge, no form of joinpoint regression or related model has been used to assess the change point in GDP, in which the impact of affluence on the mortality rate changes its direction.

To identify and evaluate the GDP level, after which the impact of wealth on the mortality rate potentially changes its direction, we introduce a form of joinpoint model (1). The method is suitable for empirical data that, split into two subsets, results in two individual regression lines. Therefore, for two separate trends, we get one particular intercept and two different slopes. The point which breaks the sample into two subsets is called a change point or joinpoint, as it changes the behaviour (trend) of the investigated data, and at the same time, joins the two trends together. Our models will be based on the functional form $y = f(x)$ and

$$f(x) = f(x; \alpha_0, \alpha_1, \alpha_2, \tau^*) \coloneqq \alpha_0 - \alpha_1(\tau^* - x)^+ + \alpha_2(x - \tau^*)^+ + \epsilon, \quad (1)$$

where $\alpha_0, \alpha_1, \alpha_2, \tau^*$ are regression coefficients. Parameters α_1, α_2, are slopes of two regression lines and τ^* is a change point. Variable *x* represents the independent variable and the expression $(A)^+$ denotes the positive part of a number A. We assume that the error term (ϵ) is randomly distributed with zero mean and a common variance σ^2 for both subsets. This model can be estimated with an adjusted ordinary least squares method.

In our study, function f describes mortality rate for chosen NCDs and change point τ^* is GDP^* – the level at which potential change in regression line of mortality rates occurs. The estimated level of affluence we will understand as a proxy of health economic threshold. Variable GDP_i represents regional or national gross domestic product per capita. That is

$$MR_i^d(GDP_i; \alpha_0, \alpha_1, \alpha_2, GDP^*) = \alpha_0 + \alpha_1(GDP^* - GDP_i)^+ + \alpha_2(GDP_i - GDP^*)^+ + \epsilon_i,$$

where MR_i^d is the age-standardised three-year average mortality rate due to an NCD d (d = 1, …, 6). As a result, for each disease, we obtain two linear functions: f_1 for the subset R_1 of lower GDP regions (for which $GDP_i \leq GDP^*, i \in \mathrm{R}_1$) and f_2 for the subset R_2 of upper GDP regions (for which $GDP_i \geq GDP^*, i \in \mathrm{R}_2$), where $f_1(GDP^*) = f_2(GDP^*)$. When assessing the relationship between mortality and affluence, two aspects are relevant: tendencies (slope of the function) and levels (mortality values, especially for constant functions). Additionally, the change point level of GDP^* and the subsequent size of subsets R_1 and R_2 are of interest.

To calculate the net effect of affluence on regional health, we use an approach based on project evaluation methodology, that is, counterfactual forecasting. These project assessment methods are used to extrapolate historical trends and measure the difference between the actual and theoretical value that would be expected otherwise without, for example, subsidy support. In project evaluation, the change point is known as it is represented by the starting point for the project. However, in our study, the change point had to be estimated, and moreover, we operate not on time but cross-sectional data.

Obtained by the joinpoint regression method, linear functions f_1 and f_2 can be extrapolated to the regions with GDP outside their respective domains. That is, the theoretical extension of the function f_2 concerns regions with lower GDP (R_1), and f_1 applies to regions with higher GDP (R_2). Operating on those theoretical functions' extensions and the empirical values, we can acquire two types of net effect values: the net effect of poverty (NE_P) and the net effect of affluence (NE_A).

First, we assess how the theoretical mortality, resulting from extrapolation of the estimated function f_2 to the subset R_1, differs from the empirical mortality levels, that is, the impact of poverty. When $MR_i^d > f_2(GDP_i)$, the actual mortality rate due to d-th disease in i-th region is higher than that which would have been reached if the general trends, typical of areas with higher GDP, were to emerge in this region. Therefore, the effect describes the number of people (per 100 thousand inhabitants) who died because the i-th region is poor, or alternatively, the number of people that could have been saved if the region i had been more prosperous, and therefore, benefited from better healthcare quality. We will identify this effect as a negative effect of poverty

$$NE\_PN_i^d = \max\{MR_i^d - f_2(GDP_i), 0\}, d = 1, \dots, 6, i \in R_1.$$

Adversely, $MR_i^d < f_2(GDP_i)$ means that the empirical mortality rate is lower than it would be if the region would be more affluent. Hence, it describes the number of people that survived because they live in the poorer region. This indicates the positive impact of poverty on regional health

$$NE\_PP_i^d = \max\{f_2(GDP_i) - MR_i^d, 0\}, d = 1, \dots, 6, i \in R_1.$$

Similarly, if we extrapolate the function f_1 to the subset R_2, we will obtain a theoretical function extending the trend of the more deprived regions to more affluent ones – the net effect of affluence. Compering this extrapolation with empirical data results in the effect NE_A. For $MR_i^d > f_1(GDP_i)$, we obtain the number of people that died because of living in a wealthy region (i.e., who wouldn't have died if their regions would be less privileged), so it describes an explicate (true) negative effect of affluence

$$NE\_AN_i^d = \max\{MR_i^d - f_1(GDP_i), 0\}, d = 1, \dots, 6, i \in R_2.$$

In the opposite case, $MR_i^d < f_1(GDP_i)$, we get the number of people that survived thanks to the region's prosperity. We recognise this as a direct positive effect of affluence

$$NE\_AP_i^d = \max\{f_1(GDP_i) - MR_i^d, 0\}, d = 1, \dots, 6, i \in R_2.$$

The proposed model and methodology are designed to detect the overall tendency, not to estimate the direct impact of GDP on mortality. This study should be viewed as an extensive correlation analysis, not as a cause-and-effect model. To obtain the latter, other important socio-economic factors need to be controlled for, such as the level of education, healthcare systems, and other socioeconomic factors. In our study, controlling for other factors would come at the cost of a correct economic interpretation of the economic threshold. A proper economic interpretation of the economic threshold requires the use of single criteria setting.

4. Results and discussion

In the first part of the study, we examine the regional dispersion and spatial patterns of mortality rates in Europe as well as the distribution of GDP per capita. In Żółtaszek and Olejnik (2017), a similar, though more detailed, analysis was carried out for death rates in 2003–2005 and 2008–2010. Figures 1 and 2 show the spatial distribution and LISA analysis for all standardised death rates of investigated NCDs.

Cancer mortality is the highest in Poland, Slovakia, Hungary, Croatia, Denmark, the northern UK, parts of the Netherlands and the Czech Republic. Regions with low mortality are mainly found in southern Europe (excluding Croatia) and Scandinavia.

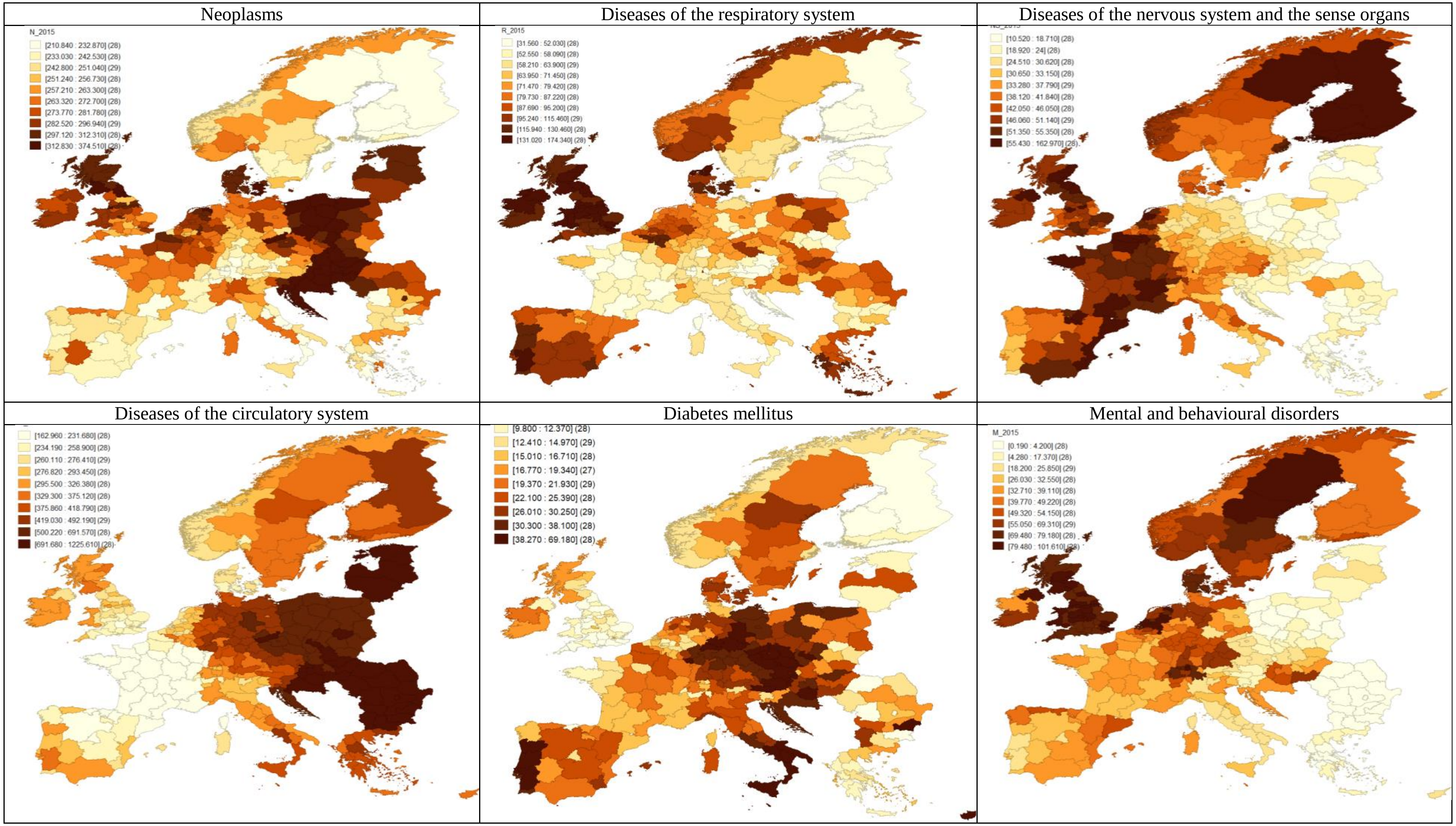
Cardiovascular diseases have an apparent spatial pattern. Regions with high mortality rates are located in Central and Eastern Europe, including the Balkans and the Baltic States. The lowest death rates are in France, Spain, and the southern UK. This bipolar East-West division is reflected in the cluster map.

In cases of mortality caused by diabetes, the highest values in 2013–2015 were observed in Portugal, Germany, Hungary, Austria, the Czech Republic, southern Italy, Cyprus, Croatia, and a few regions in Poland as well as the Severoiztochen region in Bulgaria. Low mortality can be found mainly in the UK, Finland and Greece. This distribution is reflected in significant hotspots and coldspots across Europe.

A different tendency occurs for mental and behavioural disorders as well as neurological diseases. The former account for the highest number of deaths in the UK, Scandinavia, Netherlands and Switzerland, creating four hotspot clusters. In turn, low mortality occurs in Central and Eastern Europe, except for Hungary, forming almost one large cluster. Nervous system and sensory diseases have the highest mortality rates in Scandinavia (especially Finland), with rates, on average, three times higher than in other countries. This is reflected in a distinct hotspot. Regions with relatively high mortality are located in France, southern Spain, Benelux, Great Britain and Ireland. Central and Eastern Europe have minor death rates due to diseases of the nervous system forming voluminous coldspot. For both groups of disorders, we observe a similar spatial pattern, opposite to cardiovascular conditions.

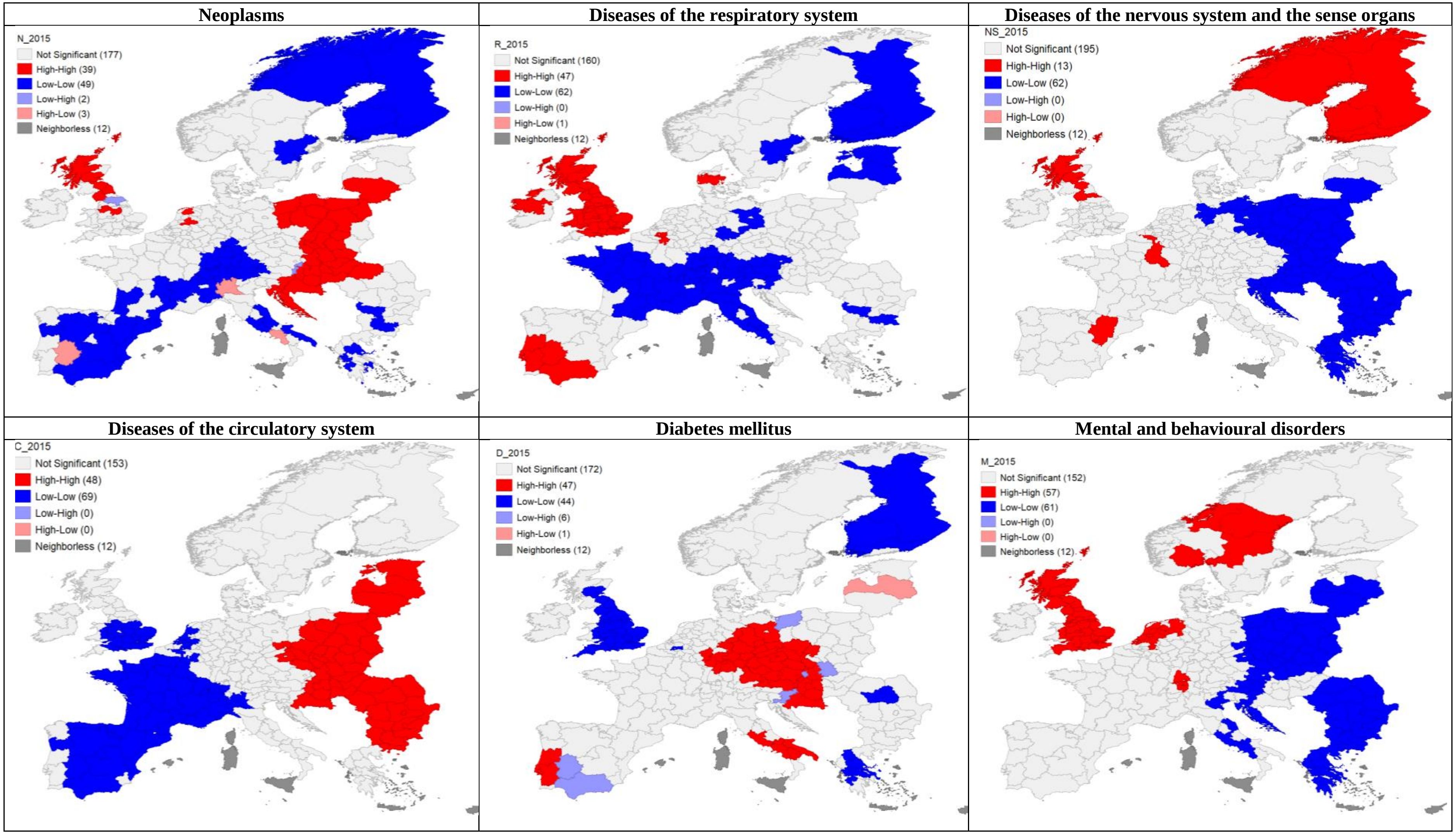
Respiratory diseases are the most common cause of death in the UK, Ireland, exterior Iberian Peninsula, Denmark and partly Greece, Belgium, and Norway. The southern part of the Iberian Peninsula and Great Britain, except for Northern Ireland, are the main mortality hotspots. The lowest mortality rates are observed in Finland, the Baltic states, France, Switzerland, Austria, Croatia, and partly Italy, confirmed by the large coldspots on the LISA map.

Fig. 1. Standardised death rates of diseases of affluence, average 2013–2015 by region of residence, in deciles.



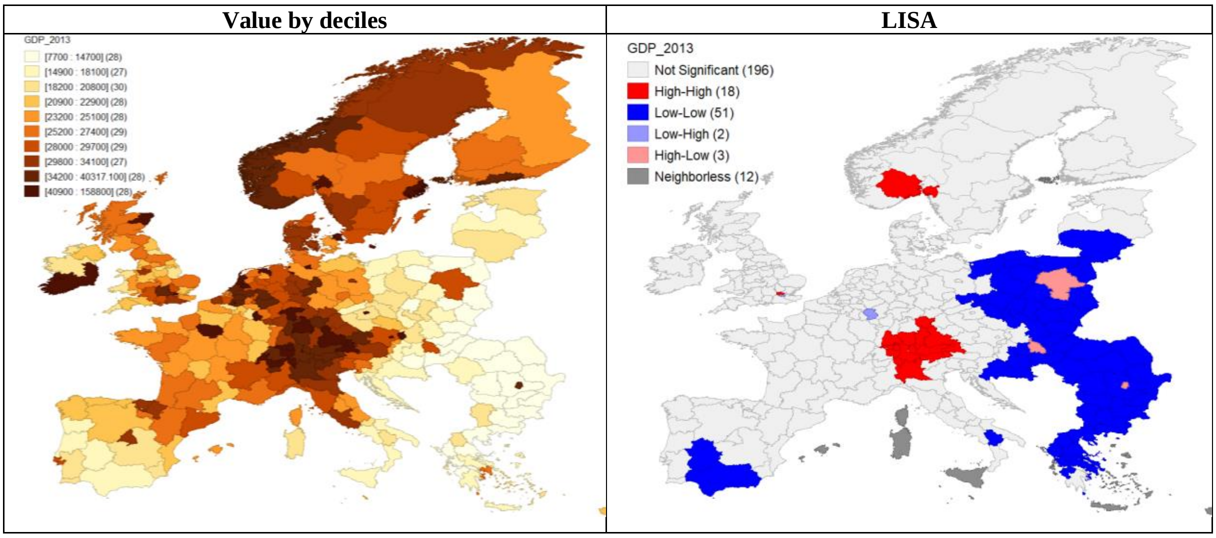
Source: Author's compilation

Fig. 2. Univariate LISA for diseases of affluence standardised death rates, averages 2013–2015 by NUTS 2 EU regions.



Source: Author's compilation

Fig. 3. GDP in euro per inhabitant, 2013, by NUTS 2 EU regions.



Source: Author's compilation

To analyse the relationship between respective mortality rates and affluence, we consider respective Pearson's correlation coefficients (Table 2) together with the spatial distribution of GDP (including clusters) presented in figure 3.

Among selected NCDs, mental and behavioural disorders have the highest positive and significant relationship with affluence. More impoverished regions of Poland and the Balkans have much lower mortality than more prosperous provinces in the UK, Scandinavia and Benelux. A similar pattern can appear for diseases of the nervous system and the sense organs. These two categories of illness seem to reflect the negative impact of affluence. In turn, diabetes, cardiovascular conditions, and neoplasm show opposite tendencies with a negative but significant correlation to GDP. More affluent regions correspond with a lower mortality rate, which may indicate better healthcare. In the case of respiratory system diseases, no clear pattern of GDP-mortality relationship can be seen.

Table 2. Correlation coefficient with GDP per inhabitant 2013 with average selected age-standardised mortality rates 2013–2015.

Disease	Correlation coefficient	p-value
Neoplasms	−0.222	0.0002
Diseases of the circulatory system	−0.393	0.0001
Diabetes mellitus	−0.125	0.0360
Mental and behavioural disorders	0.308	0.0001
Diseases of the nervous system and the sense organs	0.235	0.0001
Diseases of the respiratory system	−0.058	0.3310

Source: Author's compilation

In the second step, we assess the net effect of affluence on mortality and health economic threshold. Table 3 presents the estimation results of joinpoint regression, described in Section 3. The analysis shows that the health economic threshold GDP^* is different for each disease group. However, except for neoplasms, all change points are around 20 thousand euros per capita, ranging from 17 thousand for diabetes to almost 23 thousand for mental and behavioural disorders. As a result, although the sets of more impoverished (R_1) and more affluent (R_2) regions are not the same for each of those disease categories, the differences are not significant. Thus, 20 thousand euros is the limit at which the positive or negative wealth impact trend changes or reverses. Figure 4 offers the plots of joinpoint regression for each disease based on the estimation results, where figure 5 presents the spatial distribution of approximated net effects.

Table 3. Results of joinpoint regression with an estimated change point – GDP^* for selected NCDs age-standardised mortality rates 2013–2015.

Disease		Parameter	t-stat	p-value	GDP*
Neoplasms					37 286.59
	α_1	−0.0011	4.71	<0.001	
	α_0	256.63	77.37	<0.001	
	α_2	–	–	–	
Diseases of the circulatory system					21 397.82
	α_1	−0.0514	19.01	<0.001	
	α_0	321.09	34.77	<0.001	
	α_2	–	–	–	
Diabetes mellitus					16 999.90
	α_1	–	–	–	
	α_0	23.21	27.19	<0.001	
	α_2	−0.0001	2.28	0.024	
Mental and behavioural disorders					22 893.41
	α_1	0.0041	11.20	<0.001	
	α_0	50.42	33.29	<0.001	
	α_2	–	–	–	
Diseases of the nervous system					22 301.10
	α_1	0.0028	9.04	<0.001	
	α_0	44.60	37.93	<0.001	
	α_2	–	–	–	
Diseases of the respiratory system					17 710.68
	α_1	0.0026	2.43	0.016	
	α_0	90.25	34.85	<0.001	
	α_2	−0.0003	1.98	0.049	

Source: Author's compilation

In the case of neoplasms and diseases of the circulatory system, the joinpoint regression function patterns seem similar. With growing wealth, the number of cases decreases (for subset R_1) and then stabilises after passing the change point. That means that no matter how wealthy the region is, it is not possible to reduce the number of deaths above the change point.

Contrary to the incidence, due to the lower effectiveness of oncological treatment, the cancer death rate is higher in poorer regions than in more affluent ones. For instance, the number of new cases of breast cancer (per 100 thousand women) is greater in western and northern Europe, while the mortality rate is noticeably higher in the central and eastern regions of the European Union (EU). The European Cancer Information System (ECIS) reports that: (1) higher number of new cases is caused not only by higher prevalence (due to, e.g., 'reproductive factors, increasing obesity and physical inactivity') but also screening intensity, (2) mortality due to breast cancer declines mostly because of 'effective treatment and tools for detecting the disease at early stages' (Breast cancer burden… 2020:1-2). A similar East-West pattern occurs for colorectal cancer, resulting from uneven healthcare expenditures and the quality of screening, diagnosis, and treatment (Colorectal cancer burden… 2021:1-2). Also, WHO highlights that low-income countries and low economic level subpopulations are more burdened by cancer cases and deaths (WHO report on cancer… 2020:13-35). The critical barriers in the early diagnosis and treatment of cancer include financial and logistic obstacles, that is, availability and affordability (WHO: Barriers to early cancer diagnosis…). These observations find confirmation in our study as the mortality is higher for more impoverished regions.

The estimated GDP threshold for neoplasms is the highest among the selected diseases (37 thousand euros per capita). Hence, only in the 38 wealthiest regions in Europe, a stabilisation of the mortality level is observed, and a further reduction in cancer mortality does not appear to be possible. This confirms the WHO findings that some types of neoplasms have lower or decreasing (over time) mortality only in countries with high Human Development Index compared to low, medium and even high levels of development. It suggests that the predetermined number of deaths (in Europe, 257 people per 100 thousand inhabitants) depends not on the system solutions but external determinates. Possibly unwillingness or inability to avoid the main risk factors (obesity, alcohol, occupational exposures and air pollution) and psychological, social or cultural barriers in consulting health professionals as soon as symptoms appear may be an inevitable cost of socioeconomic development (WHO report on cancer… 2020: 14, 58-66). Hence, the levelling of mortality for more prosperous regions can be viewed as both a positive (because of relatively low mortality) and negative (no further decrease in mortality with higher GDP is possible) effect of affluence.

On the other hand, 87% of NUTS 2 regions are allocated in the more impoverished subset. While the descending tendency is a benefit of increasing prosperity, some areas are burdened with soaring death rates. From the net effect map, the distribution of people who died due to the region's low prosperity is seen (negative effect of poverty – NE_PN; see Fig. 5). The highest mortality and the most significant loss from economic underdevelopment were recorded in Southern Transdanubia (HU23), in the southwestern part of Hungary. In 2013, the area was the 12th least-developed European region (Regional Innovation Monitor Plus…). The former coal and uranium mining region, sparsely populated with many poorly accessible settlements, has an almost 39% higher cancer mortality rate than the European average (374.51 HU23 vs 269.28 EU). The estimated excessive number of deaths for this region is 117.88.

Eastern and Central Europe, as well as Baltic states, are, in general, encumbered with excessive mortality. Due to a high change point ($GDP^{*} \approx 37$ thousand euros per capita), even many northern parts of Germany and France as well as Denmark, Benelux and the UK face a similar problem. The results highlight the importance of affluence in reducing mortality through cancer screening, early detection and treatment, conditioned by availability and affordability. Furthermore, delaying the treatment makes it more expensive, less effective, and disabling, which burdens the less affluent regions (WHO report on cancer… 2020: 14, 72-84).

With a slope of −0.05, the cardiovascular mortality rate shows a steep decline with increasing affluence for 32% of less prosperous regions. This suggests a positive effect of wealth. On the other hand, the absolute number of additional deaths, described by net effect (negative effect of poverty, i.e. NE_PN), is exceptionally high in Central and Eastern Europe, up to 905 deaths (per 100 thousand inhabitants) in Northwestern Bulgaria (BG31). With the lowest-ranked economy not only in Bulgaria but in the EU as a whole, this region has the lowest life expectancy in Europe. Bulgaria's average death rate from coronary heart disease is one thousand compared to almost 400 for EU (Eurostat Data). In 2015, the cumulative number of persons living with cardiovascular disease (age-standardised, per 100 thousand) in Bulgaria was 44% higher than the EU average (Wilkins et al. 2017: 61-63).

The bipolar East-West net effect pattern that emerged from our study corresponds with the WHO cardiovascular disease risk assessment for Europe. According to WHO, in all subcategories (by age, sex, diabetes, smoking etc.), the chances of acquiring a coronary issue are noticeably higher in Central and Eastern Europe than in Western countries. Globally, over 75% of deaths due to cardiovascular problems occur in low- and middle-income countries (WHO updates Cardiovascular Risk Charts, 2019, WHO Factsheet: Cardiovascular diseases… 2021).

After passing the change point of 21 thousand euros per capita, the cardiovascular death rate stabilises at 321 deaths (per 100 thousand inhabitants) – a quarter of the maximal value. However, it is still higher than for any other disease, except for 20 regions in the case of neoplasms. Similar to cancer, after reaching GDP^*, a further reduction in mortality seems impossible – again, the positive and negative wealth effect at the same time. This may indicate that a healthy and active life does not reach a certain group of people, preventing even a well-financed and equipped healthcare system from protecting them. As suggested by WHO, most cardiovascular problems can be averted by addressing certain behavioural risk factors (tobacco use, harmful drinking patterns, unhealthy diet, obesity, and physical inactivity). Therefore, the reluctance to change the lifestyle and to undergo regular diagnostics may create an impassable boundary preventing the further decline in mortality accompanying the increase in wealth (WHO Factsheet: Cardiovascular diseases… 2021).

The lowest health economic threshold of 17 thousand euros per capita is for diabetes. In the case of 16% of the poorest regions, the estimated death rate is around 23 per 100 thousand inhabitants. All regions, which are more affluent than the change point are experiencing a positive effect of prosperity, represented by the decreasing mortality function. As a result, the NE_AP describes the positive impact of wealth (the actual death rates are lower than those extrapolated from the tendency of more impoverished regions). The highest net effect is observed in France, Norway, parts of the UK, as well as Lithuania and Estonia. The most significant number of spared lives due to affluence (17 people per 100 thousand inhabitants) characterises București-Ilfov (RO32), which includes Romania’s capital city and ranks 54th among the most prosperous regions in Europe.

As with previous diseases, early diagnosis and treatment are key factors preventing most premature deaths. However, the leading pharmaceuticals include basic diagnostics, such as blood glucose testing, which should and, in EU states, often are available in primary healthcare as well as affordable insulin. Compared to expensive procedures and medications needed to treat other NCDs, reducing diabetes mortality is relatively cheap (WHO Report: Global report on diabetes 2016: 7, 47-61, WHO Report: Classification of diabetes… 2019: 5-11). The positive impact of wealth is achieved rather by screening, prevention and awareness of a healthy lifestyle than pricy advanced treatment. This may also be the reason for the low GDP^* change point. Additionally, there seems to be no limit in preventing deaths due to diabetes, which enhances the beneficial effect of affluence.

Diseases of the nervous system and the sense organs are often linked or overlap with mental and behavioural disorders. (NCD Alliance: Mental…, What is a neurological problem?) Hence, it is not surprising that the change point is almost identical for both categories (just over 22 thousand euros per inhabitant), and they exhibit a similar pattern. For more impoverished regions, the higher GDP the higher mortality rate with a slope parameter equal to 0.004 for mental disorders and 0.003 for nervous system diseases. After crossing the change point, more affluent areas, utilising well-functioning and well-equipped health services, manage to balance the consequences of those diseases and stop that disturbing trend.

Unfortunately, with for more prosperous regions, no trend reversal can be observed. The mortality stabilises at the level of 45 people per 100 thousand population for nervous system diseases and 50 for mental and behavioural disorders. This pattern may be interpreted as a positive effect of poverty – the poorer region, the lower mortality (NE_PP). Limiting the increasing mortality trend is only a semi-positive effect of affluence – no further rise for reacher regions. This is partly a consequence of the growing prevalence accompanying affluence. Current healthcare systems find it challenging to overcome the stress, sleep deprivation, and unhealthy diet habits that come with modern lifestyles.

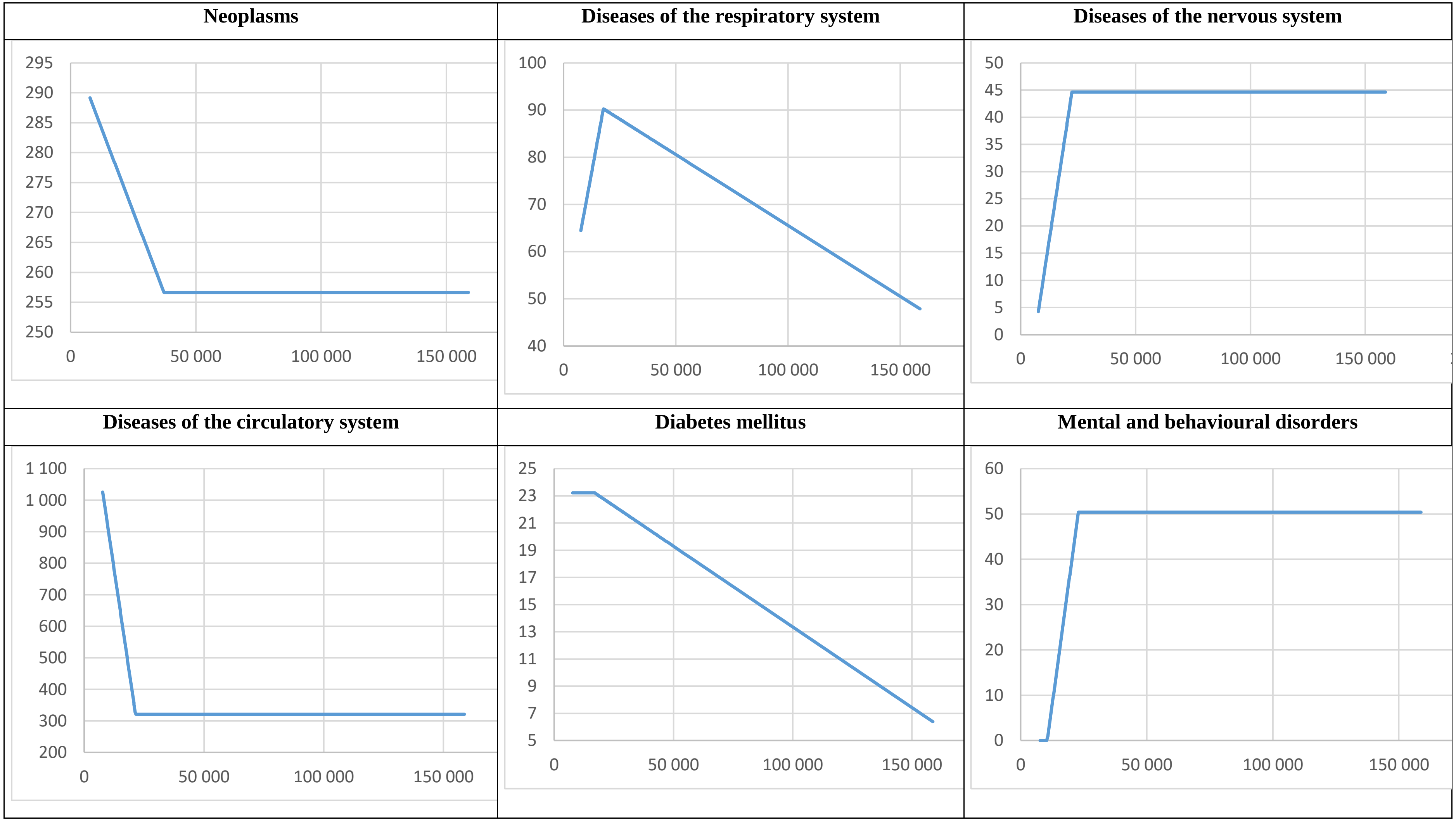
It seems that less prosperous regions may benefit from lower prevalence. As can be read from the map, the number of people who did not die from these disorders because of living in impoverished regions is the greatest in Central and Eastern Europe as well as the Iberian Peninsula and southern Italy. The top values are found in Poland – for mental disorders in the Opolskie region (PL52, 50 people per 100 thousand inhabitants) and in the case of neurological conditions in the Zachodniopomorskie region (PL42, 34 people per 100 thousand population).

Numerous neurological and mental conditions can be congenital, hereditary or onset due to injury or illness. Still, risk factors (e.g., lifestyle, stress, older age, tobacco, drug and alcohol use, unhealthy diet, physical inactivity, environmental exposures, such as pollution) are also of high importance (WHO Report: Neurological disorders… 2006: 42-182, NCD Alliance: Mental…). Moreover, though those diseases can be effectively treated at a relatively low cost, according to WHO, in most countries the quality and quantity of healthcare are insufficient to meet the demand. The structure of medical services, even in prosperous regions, is not adjusted to the evolving prevalence of neurological and mental disorders. This disparity between the needs and supply results from ‘severe human rights violations, discrimination, and stigma‘ as well as obsolete health policies (WHO: Mental health, WHO Report: Mental health… 2018:2-48).

In the case of respiratory system diseases, the correlation coefficient with GDP is insignificant. However, the correlation for the subset of more impoverished regions is positive and significant (0.3, p = 0.03), while for the subset above, the change point is negative and can be considered relevant (−0.12, p = 0.07). Nevertheless, the estimation results must be interpreted with caution, and no definitive conclusions should be drawn. We may infer that probably for poorer regions, mortality increases with higher GDP, which indicates a disease of affluence. The function changes and higher prosperity corresponds with lower death rates above the change point of almost 18 thousand euros per inhabitant. The net effect NE_AP (positive effect of affluence) reflects the number of people that survived because of being rich. The highest values are observed in Finland, with a maximum of 56 people per 100 thousand inhabitants for South Finland (FI1C), Sweden and Western Europe.

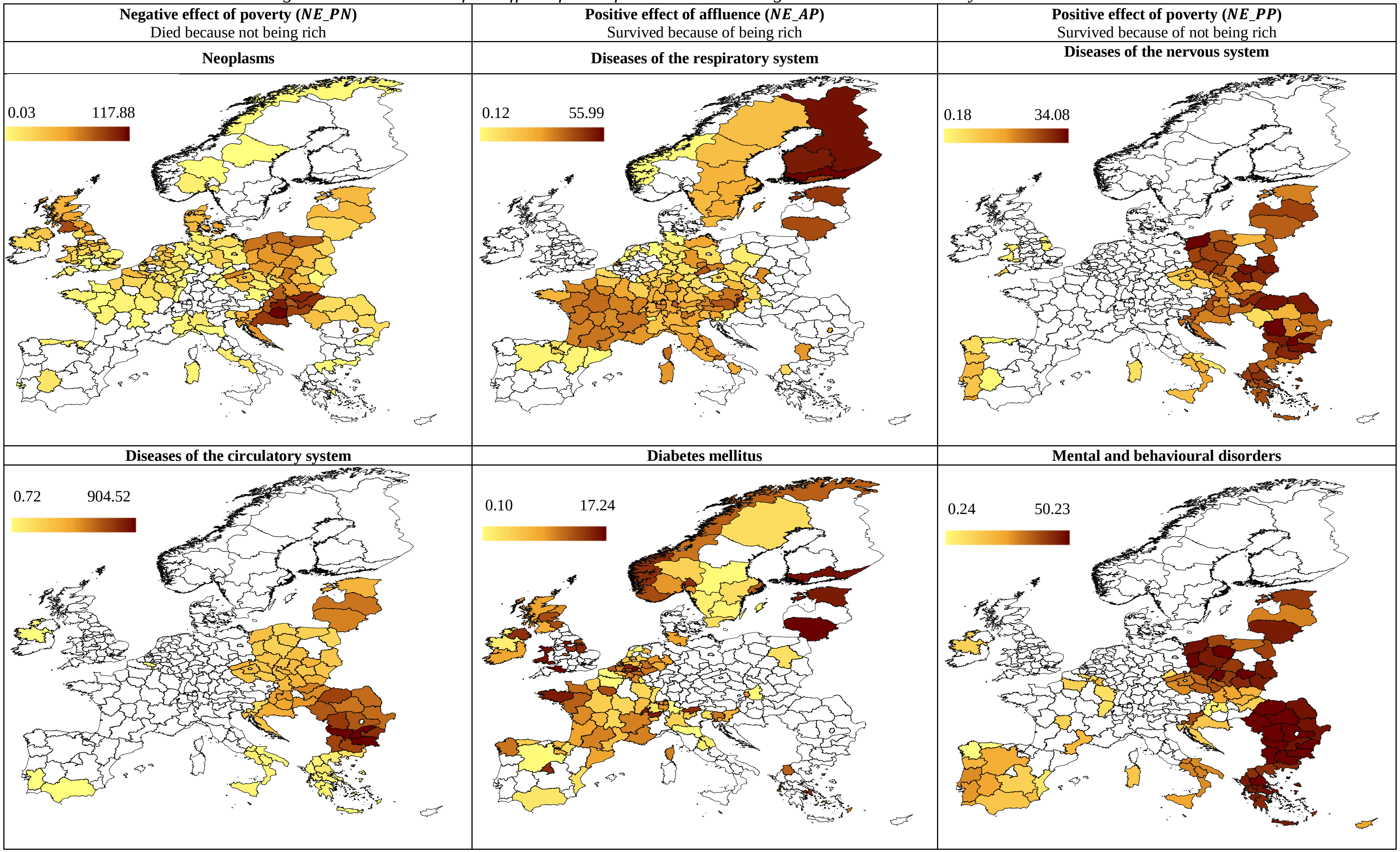
As indicated by the WHO studies, in many respiratory illnesses, risk factors are key determinates of health. The most common include smoking, air pollution, occupational chemicals and dust, obesity, and frequent lower respiratory infections during childhood. (WHO: Chronic respiratory diseases) For asthma, which is the most common respiratory disease and most common chronic disease among children, 'most asthma-related deaths occur in low- and lower-middle-income countries, where under-diagnosis and under-treatment is a challenge' (WHO: Asthma).

Fig. 4. Plot for joinpoint regression with an estimated change point for selected NCDs age-standardised mortality rates 2013–2015.



Source: Author's compilation

Fig. 5. Absolute values of net effect of GDP for selected NCDs age-standardised mortality rates 2013–2015.



Source: Author's compilation

5. Conclusions

A predetermined list of Western diseases has never been compiled because the relationship between health and wealth is complex and impermanent in time and space. The same ailment can be a disease of affluence in one part of the world and poverty in another. With the advancements in medicine and technology, which are also linked to the affluence level, some conditions can be eliminated or at least treated so that the negative wealth factor becomes irrelevant. At the same time, social, economic and technological development constantly introduces new risk factors. The relationship between wealth and 21st-century diseases is therefore not linear or constant in strength and sign. Hence, this relationship is elusive and often indirect, making it difficult to distinguish, analyse and counteract.

In our paper, we managed to assess and quantify the net effect of affluence on the prevalence of selected non-communicable diseases in European regions. We demonstrated that the link between those diseases and wealth undoubtedly exists, and in most cases this correlation is nonnegative for more impoverished regions. Hence, for less affluent locations, prosperity increases mortality.

Our study shows, however, that for each disease, there is a certain level of wealth that reverses or blocks this disturbing trend. With only two exceptions, diseases of the circulatory system and neoplasms, we observe that for poorer regions the higher prosperity, the lower mortality. After crossing the change point the stabilization occurs. For these conditions, the overall effect of affluence is positive. On the contrary, for neurological diseases, as well as mental and behavioural disorders, the global impact of wealth on health is detrimental. Among more impoverished regions the mortality is higher for more prosperous ones, and for richer regions the mortality stabilises at a disturbingly high level.

However, none of the investigated diseases seems to exhibit the true negative effect of wealth (NE_AN), that is, an unbounded rise of mortality with wealth for affluent regions. This finding doesn’t negate the harmful impact of affluence on prevalence of diseases and death rates. It emphasises, though, the role of well-functioning healthcare systems and enhanced preventive actions combined with higher awareness. Note that for five NCDs, health economic thresholds are relatively low (below 23 thousand euros per inhabitant). Therefore, as relatively few regions are disadvantaged, it stands to reason that the healthcare policy should be more locally diversified to allow for national and European health convergence. A more localised perspective and approach would counteract the adverse effects of wealth and improve the population's health. The exception is neoplasms, for which the expensive treatments exceed the financial and technical capabilities of healthcare systems for the majority of regions.

As shown, due to increasing prevalence and mortality the neurological diseases, mental and behavioural disorders are the plague of the 21st century. Unfortunately, as no positive effect of affluence has been observed (there is no level of GDP that would reverse this dangerous trend), a major change in the healthcare approach seems necessary. The evolution of health policy should prioritise these medical conditions, diverting resources and increasing public awareness. Only by directly addressing this issue with long-term multidimensional policy, including more efforts in prevention, diagnosing and early treatment, can the hazardous consequences of prosperity be counteracted.

The introduction of a joinpoint regression combined with the concept of a net effect to assess mortality patterns has shown promising results. We believe that the introduced methodology may be helpful for researchers in solving other health economics issues as there seems to be ample room for its use. For instance, a similar study may be performed on other diseases and at a different level of aggregation. It would also be worth combining outcomes of prevalence and mortality.

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