



# Economics and Mathematical Modeling in Health- Related Research

Edited by Marzenna  
Anna Weresa, Christina  
Ciecierski and Lidia Filus

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# Introduction

*Marzenna Anna Weresa, Christina Ciecierski and Lidia Filus*

The COVID-19 pandemic has revealed that health is crucial to economic and social life. Healthcare systems are related to patient care, including both the treatment of diseases and disease prevention as well as the functional and institutional frameworks of the healthcare industry. The system of healthcare varies globally. Significant disparities persist between countries regarding burden of disease, the levels and sources of healthcare funding, infrastructure development, institutional functioning, public policy priorities, etc. Despite these differences, there is a common understanding that the primary goal of any healthcare system is to enhance the health of its population, in the most effective manner possible, using available resources in an as efficient manner as possible. Undoubtedly, this underlying question requires extensive continuous research.

The definition of a healthcare system evolves continuously, becoming broader and more complex over time. A healthcare system consists of many elements, such as access to comprehensive medical care along with health promotion, disease prevention, financing schemes, share of government responsibility in health, etc. In view of this broad definition of a healthcare system, this book focuses on a wide spectrum of health-related issues ranging from risk factors for developing a disease to medical treatment and frameworks for healthcare systems. Aging populations, increasing costs of healthcare, advancing technology, and challenges created by the COVID-19 pandemic require an innovative, conceptual and methodological framework. This book offers an interdisciplinary approach to studying health-related issues by combining efforts of researchers from mathematics, medicine and economics. It also explores the various problems within health sector and healthcare systems and provides examples of how these can be analyzed using a variety of conceptual frameworks and mathematical models. Results yield implications for health policy.

The key objectives of the book are as follows:

- to assess the role of risk factors, including socioeconomic conditions, as they relate to cancer incidence and zoonotic foodborne diseases;
- to identify the costs and benefits along with the practical application of a value based health care approach in improving the clinical effectiveness of treatment;

- to search for common institutional traits that improve the efficiency and overall performance of healthcare systems;
- to study select determinants of public health outcomes, including population density, bank density and public financing of research;
- to compare the performance of the pharmaceutical sector in selected countries, including but not limited to: innovation divide, share in international trade, and the perceived value of pharmaceutical companies to potential investors;
- to provide recommendations for health policy regarding the direction of health care reform in a post-pandemic era.

This book consists of three parts further divided into chapters that are devoted to various aspects of health-related issues. Part 1 includes three chapters focused on population-based concerns regarding disease incidence including but not limited to: race, ethnicity, socio-economic status and environment as factors of disease. Part 2 features four chapters ranging across a variety of health-related industries and their subsequent impact on the public health-related outcomes. Finally, Part 3 focuses exclusively on performance measures related to the pharmaceutical industry in both global and country-specific contexts.

The contribution of this book is three-fold and pertains to theoretical, empirical and methodological concerns. With regard to its theoretical contribution, the book narrows the gap in research by combining the perspective of disease treatment with institutional factors and other determinants of health care outcomes that include but are not limited to: population density, bank density, public financing of research programs devoted to health and well-being. In addition, the conceptual framework for value-based healthcare systems will be developed and discussed. In sum, this book provides an interesting framework for further complex inquiry into healthcare systems. The book also contributes to the empirical literature and in particular, to sectoral studies that extend knowledge about the functioning of the pharmaceutical industry within the global economy. These empirical analyses of the pharmaceutical industry assess the innovation divide between countries with regard to the pharmaceutical sector, which is a factor in the overall innovation gap of the world economy. The analyses are supplemented with a mapping of the international trade flows in pharmaceutical goods, which allows for tracing changes in exports and imports induced by the COVID-19 pandemic. The value of taking this sectoral approach is enhanced by the inclusion of investor perspectives regarding pharmaceutical company performance as listed by the Warsaw Stock Exchange in Poland.

The research results presented in this book have value for practitioners and in particular, for health policy makers. Policy implications based on research

findings are identified and recommendations for future policy directions are suggested.

Lastly, through its integration of economics, medicine and mathematics, this book offers new methodological insights regarding interdisciplinary research and collaboration. A variety of mathematical and statistical methods were used throughout the book including regression models, hierarchical cluster analysis, statistical modeling, and correlation analysis for studying diverse health-related issues.



**PART 1**

*Modeling of Diseases' Risk Factors:  
Implications for Patients' Treatment*







# Racial, Ethnic and Socioeconomic Disparities in Lung and Breast Cancer Outcomes

*Joe Feinglass*

## Abstract

This chapter presents findings from two health equity studies of the social epidemiology of cancer in the United States. Both these studies were designed to provide a framework for further ecosocial research on racial, ethnic, and socioeconomic disparities in health in the United States. Findings from these studies have provided a framework for a new generation of health equity research underway at the NIH-funded Chicago Cancer Health Equity Collaborative, a collaborative of three Chicago area universities focused on cancer research. The chapter describes two specific modeling approaches to the social epidemiology of lung and breast cancer. Our breast cancer study analyzed all cause survival data from 1630 hospitals and almost 600,000 breast cancer patients from the National Cancer Database (NCDB), maintained by the American College of Surgeons and the American Cancer Society. Patients diagnosed between 1998 and 2006 were followed up to 14 years through 2011. Our research sought to determine the magnitude of socioeconomic effects on all-cause mortality, adjusting for clinical risk factors, like cancer stage at diagnosis. Was there a ‘gradient’ of mortality across our synthetic measure of socioeconomic status? Lung cancer accounts for one quarter of all US cancer-related deaths, more than breast, prostate, colorectal, and brain cancer combined. Our lung cancer study used publicly available data from the state of Illinois to investigate racial and ethnic disparities in the epidemiology of lung cancer incidence, mortality, stage at diagnosis, surgical treatment and screening.

## Keywords

lung cancer – breast cancer – cancer epidemiology – social determinants of health – health equity

## 1 Introduction

Like other chronic diseases, cancer incidence and mortality rates reflect life course social determinants of health. A large body of biomarker research on the “biological embedding of experience” has established the close and persistent connections between gene expression, epigenetics and social forces (McDade & Harris, 2018). The complex interaction between childhood adversity, chronic stress, and low control over life circumstances characteristic of lower social class position explains the ubiquitous social gradient in chronic disease prevalence and premature mortality (Jones et al., 2019; McCartney et al., 2019). In the United States the social class gradient in life expectancy has become very pronounced in recent decades with growing income inequality and the continuing pervasive effects of structural racism on the health of racial and ethnic minority populations (Bailey et al., 2021; Hittner & Adam, 2020; Kawachi et al., 2005; Harris, Majmundar & Becker, eds., 2021; Zimmerman & Anderson, 2019). Cancer data, in a standardized tumor registry format that combines patient characteristics at diagnosis with rigorous long-term follow-up, provides many opportunities to model the social patterning of cancer incidence, treatment and survival (Krieger et al., 2019).

This chapter provides findings from two recent investigations that illustrate the potential of modeling cancer health disparities. The studies are representative of the work of the National Institutes of Health-funded Chicago Cancer Health Disparities Collaborative (CHEC), a research consortium between Northwestern University, the University of Illinois at Chicago and Northeastern Illinois University. CHEC scholars combine community-engaged research with epidemiologic analyses focused on the social patterning of cancer incidence and outcomes. The two studies presented here model socioeconomic and racial disparities in breast and lung cancer, respectively, using publicly available, de-identified data.

Lung cancer, closely linked to smoking, has long been known to have a strong socioeconomic gradient in incidence related to the fact that lower income Americans are much more likely to be smokers (Barbeau et al., 2004). Conversely, breast cancer is more common among women from higher socioeconomic status communities, related to risk factors like higher alcohol consumption, fewer children, having children at a later age, and greater use of birth control pills and postmenopausal hormones (Robert et al., 2004). This has remained true even after a mid-2000s reduction in white women’s cancer incidence related to reductions in hormone replacement therapy (National Cancer Institute, 2014; Krieger et al., 2010). Just as lung cancer incidence reflects the historic toll of smoking for different birth cohorts, breast cancer incidence and staging have also evolved in tandem with changing social conditions (Krieger

et al., 2010, 2011). It was therefore of interest to analyze recent data on social disparities in outcomes within these two disparate patient populations. Both studies use publicly available, de-identified cancer data to shed light on the specific social gradient of each type of cancer. Each study provides evidence of the socioeconomic, racial, and ethnic patterning of cancer outcomes in the United States. These findings, which highlight the extent of unfair and avoidable differences in population health, have important implications for cancer prevention and control going forward.

## 2 Socioeconomic Status and Breast Cancer Outcomes

Racial differences in breast cancer mortality between White and Black women in the United States have been attributed to the fact that minority women were consistently diagnosed with higher stage cancer and often received less than optimal treatment (Clegg et al., 2009; DeSantis et al., 2010; Gumpertz et al., 2006; Krieger et al., 2012). However, much less is known about socioeconomic status (SES) disparities in outcomes for women diagnosed with breast cancer. Both breast cancer specific and all-cause mortality have been shown to vary by socioeconomic status in earlier studies (Albano et al., 2007; Byers et al., 2008). However, more recent population-based breast cancer mortality rates, measured across income quintiles, appear to have largely converged across SES categories (Albano et al., 2007).

Our breast cancer outcomes study was undertaken to estimate the effect of socioeconomic status (SES) on all cause mortality among women diagnosed with breast cancer. We were interested in modeling the independent effects of socioeconomic status at the time of diagnosis after controlling for health insurance status, race and ethnicity, breast cancer stage at diagnosis, and surgical and adjuvant treatment received (Feinglass et al., 2015). Our survival estimates were based on vital status follow-up through 2011 of over 582,000 female patients using records from the National Cancer Data Base (NCDB). We presented estimates of SES associations with all-cause mortality during a period of important changes in breast cancer diagnosis and treatment, and coinciding with a significant reduction in average person-years of life lost due to breast cancer in the US (Soneji et al., 2014).

## 3 Breast Cancer Study Methods: Data Source and Patient Sample

The NCDB is a joint project of the American Cancer Society and the Commission of Cancer of the American College of Surgeons (<http://ncdbpuf.facs.org>). NCDB

hospital-based cancer registries include patient demographics, American Joint Committee on Cancer staging and surgical and adjuvant treatments. Our sample included all female patients diagnosed with breast cancer at 1630 NCD B reporting hospitals with up to 176 month follow-up through 2011, for female patients diagnosed in 1998–2006. NCD B de-identified data were ruled exempt by the Northwestern University Institutional Review Board.

We categorized patients' age group and race and ethnicity (non-Hispanic White non-Hispanic Black, Hispanic, Asian, and other/unknown). Pathological staging was used whenever available; if missing, clinical staging was used. Treatment variables included primary surgery type (lumpectomy, mastectomy, or no or unknown primary surgery), radiation therapy, chemotherapy, or hormone therapy. One sensitivity study included the Charlson/Deyo Comorbidity Score, which is based on codes for chronic diseases, was trichotomized as 0, 1, or 2 or greater (Deyo et al., 1992) for patients diagnosed in 2003–2006 (32.8% of the sample). We also tested the sensitivity of our final model with analyses restricted to the 82.1% of patients diagnosed with Stage I–IV breast cancer, excluding patients diagnosed with DCIS.

Multivariable survival analyses were controlled for regional location of the treating hospital (large urban region, medium urban region, small urban region, rural region, or unknown), and whether a hospital had an academic/research designation or was a community institution. We created three time periods (1998–2000, 2001–2003, 2004–2006) to control for trends in diagnosis and treatment over the study period. We excluded records for patients with missing zip codes ( $n = 28,410$ , 4.65%) or stage at diagnosis ( $n = 22,239$ , 3.68%).

### 3.1 *Creating a Socioeconomic Status Measure*

In the United States, population-based direct measures of social class or social position are scarce or non-existent. Usually social class is inferred from (usually self-reported) household income or from an individual's educational attainment level. For hospital data, researchers have to attribute individual patient education or income to the patient's postal zip code average. Postal zip code, which has been mapped to census tract data as Zip Code Tabulation Areas (ZCTAs) is the smallest publicly available census data that can be matched to patient's residential zip code. The NCD B includes patient ZCTA quartile of education and quartile of income as two separate variables.

Jointly including both ZCTA education and income quartiles, even if interaction terms are estimated, fails to fully measure the synergistic effect of these measures of socioeconomic status (SES). To illustrate this, our study constructed a six-level measure from combined zip code quartiles of census-based

median income and educational attainment at the time of diagnosis. To validate this monotonic SES scale, we first used Cox Proportional Hazards models to rank hazard ratios for all 16 combinations of income and education zip code quartiles. Based on those results, we then aggregated patients into five SES categories with almost completely non-overlapping hazard ratio 95% confidence intervals. The reference for analyses was patients living in the highest income and highest education quartile (about one-third of the sample). Finally, we included a variable for patients who were uninsured or had Medicaid coverage at the time of their diagnosis as an additional indicator of SES that has been directly associated with higher breast cancer death rates (DeSantis et al., 2010).

#### 4 Survival Modelling

Cox proportional hazards regression was used to calculate initial hazard ratios for our SES measure after confirming proportional hazards assumptions graphically. The Kaplan Meier estimator and log rank test were used to test the significance of bivariate survival probabilities. Chi square tests of proportions were used to test the significance of baseline SES differences. Hierarchical Cox proportional hazards models were then used to test the significance of SES controlled for other patient and hospital covariates, with standard errors adjusted for intra-group correlation (clustering) within hospitals using STATA Version 12 (College Station, Texas) software. Differences across SES category hazard ratios were examined sequentially before and after adding insurance status, race and ethnicity, stage at diagnosis, and finally, treatment modalities.

#### 5 Results of Breast Cancer Survival Modelling

Overall five and ten year survival probabilities for all 582,396 female breast cancer patients were 84.6% and 69.2%; respectively. Survival probabilities were 93.5% and 82.2% for the 104,055 patients (17.9%) diagnosed with DCIS, 11.3% and 13% higher survival than invasive cancer patients. While only 7.3% of breast cancer patients were from the lowest quartile education and income ZTCAS, 32.5% were from highest quartile education and income ZCTAS. As expected, Black and Hispanic patients composed much larger proportions of lower SES categories, with Blacks composing 27.3% of the lowest SES category. Conversely, 89.8% of the highest SES patients were non-Hispanic Whites ( $p < 0.001$ ). Five year survival for the highest SES group was 87.8% as compared

to 79.5% for the lowest SES group; at 10 years the difference was 10% (71.5% to 61.5%,  $p < 0.001$ ). Highest SES patients had an 11.5% greater use of lumpectomy versus mastectomy and 1.8% lower proportion of no or unknown surgery, an 8.1% greater use of radiation therapy, a 2.4% greater use of chemotherapy and 4.8% greater use of hormone therapy as compared to lowest SES patients. Table 1.1 shows the original 16 possible categories collapsed across six categories with virtually non-overlapping hazard ratios. There was a clear SES gradient in survival with a 69% greater hazard ratio for the lowest as compared to the highest SES category (all comparisons  $p < 0.001$ ).

TABLE 1.1 Mortality hazard ratios for patients diagnosed with breast cancer across six zip code income and education categories

Zip code quartile income	Zip code quartile education	Hazard ratio (95% CI)	Combined percent prevalence	Category hazard ratio (95% CI)
Lowest	Lowest	1.71 (1.66–1.76)	11.5	1.69 (1.64–1.74)
Lowest	Second	1.68 (1.61–1.75)		
Lowest	Third	1.61 (1.51–1.71)		
Second	Second	1.50 (1.46–1.55)	15.4	1.49 (1.45–1.53)
Second	Lowest	1.47 (1.42–1.53)		
Second	Third	1.47 (1.41–1.53)		
Third	Lowest	1.37 (1.31–1.43)	21.2	1.35 (1.32–1.39)
Third	Second	1.37 (1.33–1.41)		
Third	Third	1.34 (1.30–1.38)		
Lowest	Highest	1.31 (1.19–1.43)	8.2	1.28 (1.24–1.33)
Second	Highest	1.29 (1.21–1.38)		
Third	Highest	1.28 (1.23–1.33)		
Highest	Lowest	1.24 (1.14–1.34)	11.3	1.19 (1.16–1.22)
Highest	Second	1.20 (1.15–1.26)		
Highest	Third	1.18 (1.15–1.22)		
Highest	Highest	Reference	32.5	Reference

N = 582,396 Women from 1630 National Cancer Data Base Reporting Hospitals, diagnosed 1998–2006.

Table 1.2 presents the final Cox proportional hazards model results. The highest to lowest SES hazard ratio was 1.27 (95% CI 1.23–1.30), with decreasing hazard ratios across SES categories to about 12% higher hazard ratios for the fourth and fifth highest SES categories. As expected, older age was strongly associated with lower survival. Patients covered by Medicaid or who were uninsured had a 47% higher hazard ratio than those with other insurance. Black patients had a 24% higher hazard ratio than non-Hispanic Whites, while Hispanic, Asian and other or unknown ethnicity had significantly lower hazard ratios than Whites. As compared to patients diagnosed with DCIS, hazard ratios sharply increased for higher stage patients reaching 15.9 for stage IV patients. Time period indicators were not significant, while being diagnosed at an academic hospital or a hospital in a rural area were both protective. Patients with no or unknown surgery had an 82% higher hazard ratio than patients undergoing mastectomy, but there were no significant survival differences between patients undergoing lumpectomy versus mastectomy. Patients who received chemotherapy, radiation or hormone treatment all had better survival than those who received no adjuvant treatment.

TABLE 1.2 Cox regression results for all cause mortality for patients diagnosed with breast cancer

	Sample percent	Hazard ratio (95% CI)
Zip code income and education and socioeconomic status (SES)		
SES1 (lowest)	11.5	1.27 (1.24–1.31)
SES2	15.4	1.21 (1.19–1.24)
SES3	21.2	1.18 (1.15–1.20)
SES4	8.2	1.12 (1.09–1.16)
SES5	11.3	1.13 (1.10–1.15)
SES6 (highest)	32.5	Reference
Age		
39 and under	4.9	Reference
40 to 49	18.0	0.79 (0.76–0.82)
50 to 69	47.0	1.17 (1.13–1.21)
70 and over	30.1	3.70 (3.58–3.82)
Race and ethnicity		
Non-Hispanic White	83.1	Reference
Non-Hispanic Black	9.0	1.24 (1.21–1.27)



TABLE 1.2 Cox regression results for all cause mortality for patients diagnosed (*cont.*)

	Sample percent	Hazard ratio (95% CI)
Hispanic	3.9	0.85 (0.80–0.89)
Asian	2.3	0.70 (0.67–0.74)
Other or unknown	1.6	0.87 (0.83–0.92)
Regional location of hospital		
Large urban region	52.7	Reference
Medium urban region	20.4	1.04 (1.01–1.07)
Small urban region	23.6	1.01 (0.98–1.03)
Rural region	1.7	0.92 (0.88–0.97)
Unknown region	1.7	1.00 (0.95–1.06)
Type of hospital		
Academic/research	27.0	0.92 (0.88–0.95)
Community	73.1	Reference
Insurance status		
Medicaid or not insured	5.8	1.47 (1.42–1.52)
Other forms of insurance	94.2	Reference
Period		
1998–2000	33.8	1.00 (0.98–1.02)
2001–2003	33.4	1.00 (0.99–1.02)
2004–2006	32.8	Reference
Stage		
Stage 0	17.9	Reference
Stage 1	43.3	1.57 (1.54–1.61)
Stage 2	29.7	2.71 (2.65–2.77)
Stage 3	6.8	6.18 (5.99–6.37)
Stage 4	2.3	15.9 (15.2–16.6)
Radiation therapy		
Received radiation therapy	52.4	0.76 (0.74–0.77)
No radiation therapy	47.6	Reference
Chemotherapy		
Received chemotherapy	33.2	0.87 (0.86–0.89)
No chemotherapy	66.8	Reference

TABLE 1.2 Cox regression results for all cause mortality for patients diagnosed (*cont.*)

	Sample percent	Hazard ratio (95% CI)
Hormone therapy		
Received hormone therapy	41.5	0.72 (0.71–0.73)
No hormone therapy	58.6	Reference
Surgery		
No or unknown surgery	3.5	1.82 (1.73–1.91)
Lumpectomy	60.1	1.00 (0.98–1.01)
Mastectomy	36.4	Reference

N = 582,396 Women from 1630 National Cancer Data Base Reporting Hospitals, diagnosed 1998–2006 with follow-up through 2011.

## 6 Breast Cancer and Socioeconomic Status

In this study, patients' insurance, race, stage at diagnosis, and treatment modalities accounted for about two-thirds of the initially observed SES gradient. Even after controlling for these factors, patients from the lowest income and education ZCTAs still had a 27% higher hazard ratio than the highest SES patients. In secondary analyses, we found that comorbidity, while itself highly predictive of mortality, explains only a very small proportion of the remaining SES mortality gap. Despite better survival among patients with DCIS, NCDDB patients with invasive cancer were also found to have a very similar SES 'gradient' in mortality. SES disparities in treatment quality had a much weaker impact on survival than social factors.

Historical studies of breast cancer incidence and mortality reveal multiple and complex 'natural histories' of breast cancer. Biomarkers at presentation, cancer reoccurrence, and cancer mortality rates have exhibited contingent time trends (Krieger, 2013). Albano et al. analyzed population-based 2001 breast cancer death rates for women ages 25–64 by educational attainment within black and white race, and found the educational disparity was over twice as great among White versus Black women (Albano et al., 2007). Analyzing more recent county level, population-based breast cancer mortality rates, Krieger et al. (2012) found a pattern of increasing (1960–1990) and then decreasing (1990–2006) disparities in standardized breast cancer mortality rates across quintiles of county median household income for both Blacks and Whites (Krieger et al., 2012). In this study, the association of SES with all-cause mortality, above and beyond the effects of race and ethnicity, health insurance, stage

at diagnosis and treatment disparities was enduring throughout the study period across both the DCIS and invasive cancer patient cohorts.

## 7 Lung Cancer Disparities in Illinois

Our study of lung cancer disparities in the state of Illinois was conducted as part of a larger CHEC community based participatory research initiative which includes the NIH funded Supporting High Risk African American Men in Research, Engagement & Decision Making (SHARED) project, a lung cancer control study based on African American men as citizen scientist study partners. Illinois is a large, diverse state with over 12.5 million residents, over 14% Black and 17% Hispanic. To understand the epidemiologic background to racial health disparities in our state we assembled recent publicly available Illinois smoking, cancer registry and lung cancer hospital care information by Illinois resident's race and ethnicity (Golecha et al., 2021). Our findings provide the health equity modelling features needed to further analyze disparities in diagnosis, treatment, and screening rates.

## 8 Epidemiology of Lung Cancer

Related to declining smoking rates in the United States and improved care for those with lung cancer, there has been a 5% decline in lung cancer mortality in men and a 4% decline in women since 2013. However, around one quarter of all cancer related deaths in the United States and Illinois are still attributable to lung cancer. Data from 2017 indicate that there have been more lung cancer related deaths than deaths from breast, prostate, colorectal and brain cancer combined (Howlader et al., 2019; Siegel, Miller & Jemal, 2020). When detected early, lung cancer has the potential to be effectively treated (Li et al., 2016). The five year survival rate is 57% when diagnosed at local stage, unfortunately, approximately 57% of diagnoses are made in distant stage, where the five-year survival rate is approximately 5% (Siegel, Miller & Jemal, 2020). Recent data from 10 states from the Behavioral Risk Factor Surveillance System (BRFSS) survey found that only one in eight current or former smokers who met United States Preventive Services Task Force criteria for screening reported lung cancer screening in the last year (Richards, 2020).

Racial disparities in lung cancer incidence, mortality, surgical treatment and screening have been reported since the late 1990s. Non-Hispanic Blacks are both at higher risk for lung cancer than Whites in the United States, present with more advanced disease and have a worse probability of survival once

diagnosed (Mulligan et al., 2006; Underwood et al., 2012). It is important to note here that like lung cancer, other disease-specific racial disparities reflect structural racism, the social conditions in which the Black population has had to exist. For example, like many other health conditions, racial disparities in lung cancer are known to be exacerbated by residential segregation (Hayanga et al., 2013). Black residents in the most racially segregated neighborhoods in the United States had a 10% higher lung cancer mortality rate compared Blacks living in the least racially segregated neighborhoods (O’Keefe et al., 2015). Hispanic Americans, particularly those of Mexican origin, have lower smoking rates than white Americans and a younger population. Hispanics have a little more than half the lung cancer incidence and one-third the lung cancer mortality of NH Whites (Miller et al., 2018).

Recent national Surveillance, Epidemiology, and End Results (SEER) findings demonstrated a substantial decrease in age-adjusted lung cancer incidence and mortality between Blacks and Whites between 2000 and 2016. These national data suggest disparities related to lung cancer incidence and mortality are narrowing at the national level. We undertook this study to determine the extent to which lung cancer disparities in Illinois have followed or diverged from these national trends. We used recent, publicly available Illinois smoking, cancer registry and hospital care data.

## 9 Lung Cancer Study Methods

We obtained data for incidence, mortality, and stage of diagnosis from the Illinois Department of Public Health’s Illinois State Cancer Registry (ISCR) online database. Patients diagnosed with cancer are identified by the ISCR from hospital tumor registries, free standing clinics, radiation treatment facilities, laboratories, and physician offices. The incidence rate was calculated as the average annual age-adjusted (to the 2000 US standard population) rate per 100,000 Illinois residents for the years 2012 to 2016, the most recently available data. Lung cancer mortality data was available for 2016, including extent (stage) of disease at the time of diagnosis categorized as local (if a malignancy limited to origin organ), regional (if tumor extends beyond origin organ’s limits), distant (if tumor that has spread to distant sites, remote from primary tumor), or unknown stage. Stage at diagnosis is provided by race and ethnicity, with cases where patient ethnicity could not be determined reported as “other” or “unknown” included in the “all races” category.

Illinois Hospital Association Comparative Health Care and Hospital Data Reporting Services (COMPdata) administrative discharge data from 199 non-federal Illinois hospitals were obtained for all patients with codes for

malignant neoplasm of the bronchus or lung coded admitted from 2016–2018. We also identified patients undergoing lung resection surgery, which was only performed at 87 Illinois hospitals. Finally, we identified outpatient low dose computerized tomography screening (LDCT) screening. Only 114 Illinois hospitals performed LDCT in by 2018.

Because smoking history is integrally related to lung cancer incidence, we also present survey data on current or past smoking among Illinois residents age 35 or older. These data were from the 2017 Illinois Behavioral Risk Factor Surveillance System (BRFSS) survey. The BRFSS sampling methodology has been adjusted to increase the representativeness of low income and minority populations. Data were collected from 1,856 telephone interviews representative of 2,864,367 Illinois residents age 35 and older. Ever smoking was defined as having smoked at least 100 cigarettes (approximately five packs).

To compute hospital admission, surgical admission and screening rates, we obtained population denominator estimates for Illinois residents age 35 and older for all Illinois residents and for non-Hispanic White, non-Hispanic Black, and Hispanic residents using 2017 five-year averaged American Community Survey census data. We used the hospital use numerator data to construct medical admission, surgical admission, and screening rates per 10,000. We then compared rate ratios for racial and ethnic groups for each lung cancer outcome and for prevalence of ever smoking. The significance of differences in rate ratios was determined using chi square tests. All analyses were done with Stata Version 15 (College Station, TX). All data were publicly available and de-identified and thus IRB exempt.

## 10 Results of the Lung Cancer Study

As shown in Table 1.3, the age adjusted annual incidence of lung cancer in Illinois between 2012–2016 was 64.7 per 100,000 Illinois residents, but it was 75.7 per 100,000 for Blacks and only 27.2 per 100,000 for Hispanics.

There were 6,242 total Illinois lung cancer deaths in 2016. The age-adjusted mortality rate was 16.8% higher for Black versus White Illinois residents. Black and especially Hispanic residents had higher proportions of patients diagnosed at distant stage (all comparisons  $p < 0.001$ ).

Table 1.4 presents the 2016–2018 average annual rate per 10,000 displayed for each type of care.

The overall medical admission rate for NH Black patients (36.2 per 10,000 population) was 35% higher than for NH White patients (26.8 per 10,000 population). Conversely the rate of admission for medical treatment was 70% lower for Hispanic than for NH White patients (8.1 versus 26.8 per 10,000 population).

TABLE 1.3 Illinois state cancer registry data on lung and bronchus cancer incidence, mortality and stage at diagnosis by race and ethnicity

	2012–2016 number diagnosed and average annual age adjusted incidence rate per 100,000 population <sup>a</sup>		2016 number of decedents and mortality rate per 100,000		2012–2016 percent for stage			
	Number	Rate (CI)	Number	Rate (CI)	Local	Regional	Distant	Unknown
White	39,130	64.8 (64.1–65.4)	5,157	41.5 (40.3–42.6)	21.6	22.8	50.3	5.3
Black	6,939	75.7 (73.8–77.5)	967	51.3 (48.0–54.7)	17.8	21.4	54.3	6.6
Hispanic	1,373	27.2 (25.7–28.8)	n/a	n/a	12.7	19.3	61.4	6.6
All Illinois residents	47,130	64.7 (64.1–65.3)	6,242	41.5 (40.5–42.6)	20.7	22.4	51.5	5.5

a p < 0.001

TABLE 1.4 Average annual rates per 10,000 for hospital admissions, lung resection procedures and low dose CT screening for Illinois residents coded as having lung cancer (2016–2018)<sup>a</sup>

Age	Illinois population <sup>a</sup>	Medical admissions	Surgical admissions	Screening
<b>NH White</b>				
35–54	2,118,172	3.86	0.26	0.98
55–74	1,971,939	36.78	2.94	48.95
75+	641,230	71.88	3.46	11.12
All ages 35+	4,731,341	26.84	1.81	22.35
<b>Black</b>				
35–54	467,637	5.69	0.21	0.39
55–74	341,334	62.70	2.74	28.02
75+	86,621	94.93	2.35	8.74
All ages 35+	895,592	36.21	1.38	11.73
<b>Hispanic</b>				
35–54	574,601	1.24	0.10	0.19
55–74	225,472	17.92	1.08	10.17
75+	42,930	46.35	1.55	4.04
All ages 35+	843,003	8.07	0.43	3.05

a 2017 5-year American Community Survey Census Estimates, p < 0.001 all comparisons

TABLE 1.4 Average annual rates per 10,000 for hospital admissions (*cont.*)

Age	Illinois population	Medical admissions	Surgical admissions	Screening
All Illinois residents <sup>b</sup>				
35–54	3,160,410	3.84	0.26	0.82
55–74	2,538,745	40.64	3.06	44.91
75+	770,781	77.00	3.52	10.92
All ages 35+	6,883,529	25.43	1.64	18.16

b Includes other or unknown race and ethnicity.

The proportion of patients with a principal diagnosis of lung cancer was virtually identical for NH Blacks and NH Whites (27.8% versus 27.7%). Surgical admissions, which are a surrogate for earlier stage at diagnosis and more effective treatment, were almost 25% lower for Non-Hispanic Black patients and extremely rare among Hispanic patients (0.46 per 10,000). There were 36,515 LDCT screenings at Illinois hospitals from 2016–2018. The rate of LDCT screenings was almost twice as high for non-Hispanic Whites as compared to non-Hispanic Black patients and over seven times the rate for Hispanics (all comparisons  $p < 0.001$ ).

### 10.1 Smoking Rates

BRFSS data show that approximately 41% of the Illinois population age 35 or older were self-reported “ever smokers”.

Ever-smoker rates for non-Hispanic Blacks were lower than for NH Whites (45.8% to 39.4%) and much higher than Hispanics (27.2%,  $p < 0.001$ ). However, non-Hispanic Blacks did have slightly higher ever smoker rates among the age 55–74 population.

### 10.2 Lung Cancer Race and Ethnicity Rate Ratios

Figure 1.2 displays NH Black and Hispanic to NH White rate ratios for incidence, mortality, distant stage at diagnosis (for those with lung cancer), medical admissions, surgical admissions, and screening.

The incidence, mortality, distant stage at diagnosis, and medical admissions rate ratios for NH Blacks to NH Whites were all greater than 1.0, while the rate ratios for surgical admissions and screening were less than 1.0. For Hispanics to NH Whites, the rate ratio was only higher than 1.0 for diagnosis at distant stage, with incidence, mortality, medical admissions, surgical admissions, and screening the rate ratios were all  $< 1.0$ .

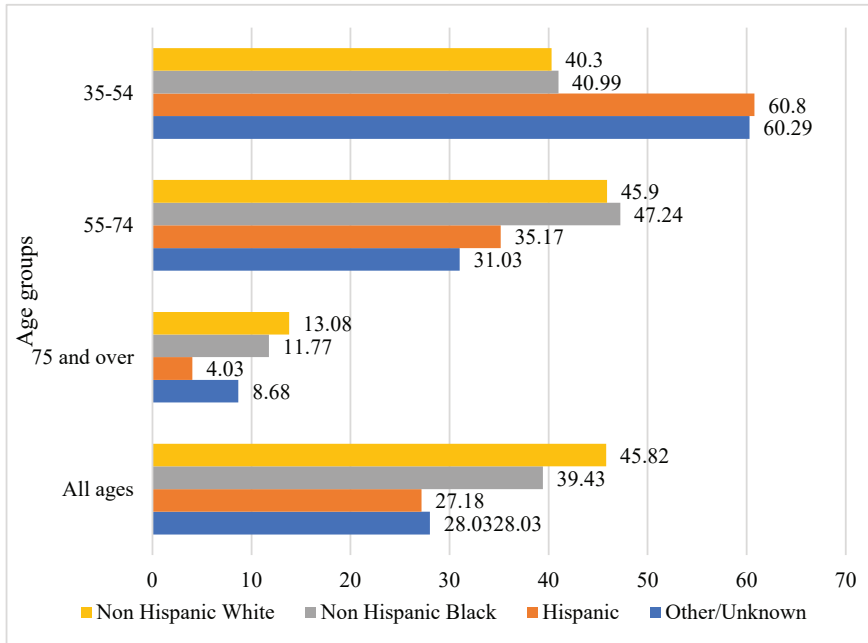


FIGURE 1.1 Percent of smokers who had ever smoked 100 cigarettes by age  
 Note: N = 1,856 telephone interviews from the 2017 behavioral risk surveillance system survey  
 SOURCE: AUTHOR’S ELABORATION

10.3 *Illinois Lung Cancer Disparities in Context*

Our study illustrates the continued presence of racial and ethnic disparities in lung cancer outcomes and care in Illinois. NH Blacks were found to have a higher incidence of lung cancer and had increased risk for mortality, late-stage diagnosis, and medical hospitalization rates while having lower surgical admission and screening rates. Hispanics had the lowest lung cancer incidence and lung cancer related medical admissions rate, which may be related to much lower rates of smoking. However, the higher rate of advanced stage diagnosis may indicate that Hispanic Illinois residents may be less likely to have medical care encounters resulting in routine imaging for other indications, which might lead to the identification of clinically asymptomatic lung cancers. This is consistent with Hispanics’ well-known differential access to primary care and health insurance (Velasco-Mondragon et al., 2016).

As compared to our Illinois findings, national on-line SEER data show a much narrower gap in incidence rates, mortality, and stage at diagnosis between NH Blacks and NH Whites. Based on 2016 data from SEER, NH Blacks had a higher age-adjusted incidence rate (56.8 per 100,000) than NH



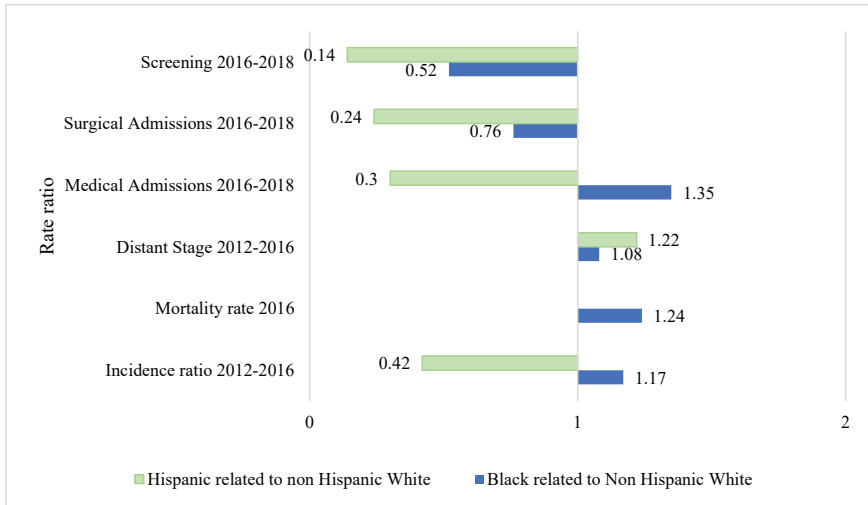


FIGURE 1.2 Rate ratio for Illinois lung cancer-related outcomes for Black related to Non-Hispanic Whites and Hispanics related to Non-Hispanic Whites  
SOURCE: AUTHOR'S ELABORATION

Whites (55.1 per 100,000) (Surveillance, Epidemiology, and End Results (SEER) Program, n.d.) which reflects a significantly lower rate ratio (1.07) than what we found for Illinois (1.17). While NH Blacks also have a higher national lung cancer mortality rate (49.6 per 100,000) in comparison to NH Whites (47.7 per 100,000) (Surveillance, Epidemiology, and End Results (SEER) Program, n.d.), this again reflects a much lower national rate ratio (1.04) than what we found in Illinois (1.24). These findings indicate the urgent need for interventions at the state and local level to address disparities in lung cancer care, where most programs to address these gaps are ultimately enacted.

Our results indicated slightly lower self-reported smoking rates for NH Black Illinois residents. This is consistent with historical research indicating that going back 40–50 years, Black Americans have consistently consumed fewer cigarettes than Whites (Ryan, 2018). However, Black smokers have a longer duration of smoking and are diagnosed with lung cancer at an earlier age, and smoking duration may be more closely associated with lung cancer incidence than pack years (Ryan, 2018). Smoking cessation may not be as successful in the Black population for reasons related to greater social stress, less medical assistance in quitting, and unequal access to healthcare (Bach et al., 2004; Shavers & Brown, 2002). Thus Black smokers do not benefit as much from the roughly 20 year linear decrease in the odds of lung cancer after a smoker quits (Ryan, 2018).

It is also been proposed that Black smokers are more susceptible to the development of smoking-induced lung cancer due to differing nicotine metabolism pathways which lead to differences in the uptake of carcinogens (Haiman et al., 2006). Blacks have higher rates of smoking more than 30 cigarettes per day, at which point metabolic pathways become saturated and toxicity increases (Haiman et al., 2006). This is supported by findings that Black smokers inhale higher amounts of nicotine per cigarette smoked when compared to Whites, a marker for extraction of carcinogens (Trinidad et al., 2010). Finally, the toll of workplace exposure to carcinogens may play a role in so far as Black workers are disproportionately represented in the least safe occupations (Stellman & Stellman, 1996).

Our findings from Illinois that both Hispanics and Non-Hispanic Blacks were more likely to be diagnosed at a later stage in comparison to Whites confirm previous studies which controlled for socioeconomic factors and tumor histology types (Chen et al., 2015). Diagnosis at later stage is likely related to poorer access to primary healthcare and much higher rates of lack of health insurance, with Hispanics having the highest rate of uninsurance. Bach and colleagues described how Black lung cancer patients were highly concentrated among a small subgroup of non-board certified physicians, and were more often treated by physicians who themselves reported challenges in gaining access to high quality services for their patients (Bach et al., 2004).

Illinois disparities in surgical admission rates echo a 1999 study done by Bach et al. on treatment for early stage non-small cell lung cancer (Bach et al., 1999). These findings were replicated in a 2009 study by Farjah et al. which found 14% racial difference among patients who were all recommended to receive surgical therapy (Farjah et al., 2009), and in a 2015 study done by Chen et al. finding that both Hispanics and NH Blacks had lower odds for receiving treatment at earlier stages even after adjusting for socioeconomic factors and tumor histology (Chen et al., 2015). Findings from a study done by Soneji et al., found that Blacks and Hispanics with early stage lung cancer had lower surgical resection rates, and that Black patients who did receive early stage lung cancer treatment experienced worse overall survival than White patients (Soneji et al., 2017). Black patients may be less likely to consent to surgical therapy, reflecting a historic lack of trust in the US healthcare system (Corbie-Smith et al., 1999; Cykert & Phifer, 2003; Gordon et al., 2006; Margolis et al., 2003). Black patients may also have less access to hospitals and surgeons providing the highest quality cancer care (Bach et al., 2004; Shavers & Brown, 2002).

Our results also align with previous findings of racial and ethnic disparities in lung cancer screening. A survey conducted by Japuntich et al. found that of among patients meeting USPSTF criteria, non-Black patients were 2.8 times

more likely to report having been screened, despite screening being covered by the Affordable Care Act (Japuntich et al., 2018). One barrier to screening is that former smokers may not believe they are susceptible to lung cancer (Delmerico et al., 2014). Rates of primary care physician referral for screening continue to remain low (Coughlin et al., 2014; O'Keefe et al., 2015).

Illinois has failed to close the lung cancer racial disparities gap and lags behind the rest of the country. Lung cancer disparities, like health status disparities in general, are rooted in the social determinants of health and will likely remain to the extent that politically patterned social, economic, and environmental inequality, based in the concentration of poor, highly segregated communities with concentrated poverty and high rates of smoking, continues to pervade American society.

## 11 Final Conclusion

These two studies on cancer health disparities provide a very introductory framework for more detailed statistical modeling that can drill down to the interactive complexity of cancer epidemiology. This is now being done in biomarker studies that describe the complex physiological effects that embody social experience (McDade & Harris, 2018). While social epidemiology research continues to document how conditions 'outside the body' get 'under the skin', the need to reduce the social conditions which produce population health disparities remains the foremost public health priority.

## References

- Albano, J., Ward, E., Jemal, A., Anderson, R., Cokkinides, V., Murray, T., Henley, J., Liff, J., & Thun, M. (2007). Cancer mortality in the United States by education level and race. *Journal of the National Cancer Institute*, 99(18), 1384–1394. <https://doi.org/10.1093/JNCI/DJM127>.
- Bach, P. B., Pham, H. H., Schrag, D., Tate, R. C., & Hargraves, J. L. (2004). Primary care physicians who treat blacks and whites. *New England Journal of Medicine* 351(6), 575–584. <https://doi.org/10.1056/NEJMSA040609>.
- Bach, P., Cramer, L., Warren, J., & Begg, C. (1999). Racial differences in the treatment of early-stage lung cancer. *The New England Journal of Medicine*, 341(16), 1198–1205. <https://doi.org/10.1056/NEJM199910143411606>.
- Bailey, Z., Feldman, J., & Bassett, M. (2021). How structural racism works – racist policies as a root cause of U.S. racial health inequities. *The New England Journal of Medicine*, 384(8), 768–773. <https://doi.org/10.1056/NEJMMS2025396>.

- Barbeau, E. M., Krieger, N., & Soobader, M.-J. (2004). Working class matters: Socioeconomic disadvantage, race/ethnicity, gender, and smoking in NHIS 2000. *American Journal of Public Health, 94*(2), 269. <https://doi.org/10.2105/AJPH.94.2.269>.
- Byers, T., Wolf, H., Bauer, K., Bolick-Aldrich, S., Chen, V., Finch, J., Fulton, J., Schymura, M., Shen, T., Van Heest, S., & Yin, X. (2008). The impact of socioeconomic status on survival after cancer in the United States: findings from the National Program of Cancer Registries Patterns of Care Study. *Cancer, 113*(3), 582–591. <https://doi.org/10.1002/CNCR.23567>.
- Chen, Y., Chang, A., Chen, C., & et al. (2015). 1036 Impact of race and ethnicity on stage at diagnosis of non-small cell lung cancer (NSCLC) and receipt of treatment in contemporary United States population: A SEER-based analysis. *European Journal of Cancer, 51*.
- Clegg, L., Reichman, M., Miller, B., Hankey, B., Singh, G., Lin, Y., Goodman, M., Lynch, C., Schwartz, S., Chen, V., Bernstein, L., Gomez, S., Graff, J., Lin, C., Johnson, N., & Edwards, B. (2009). Impact of socioeconomic status on cancer incidence and stage at diagnosis: Selected findings from the surveillance, epidemiology, and end results: national longitudinal mortality study. *Cancer Causes & Control: CCC, 20*(4), 417–435. <https://doi.org/10.1007/S10552-008-9256-0>.
- Corbie-Smith, G., Thomas, S. B., Williams, M. V., & Moody-Ayers, S. (1999). Attitudes and beliefs of African Americans toward participation in medical research. *Journal of General Internal Medicine, 14*(9), 537. <https://doi.org/10.1046/J.1525-1497.1999.07048.X>.
- Coughlin, S., Matthews-Juarez, P., Juarez, P., Melton, C., & King, M. (2014). Opportunities to address lung cancer disparities among African Americans. *Cancer Medicine, 3*(6), 1467–1476. <https://doi.org/10.1002/CAM4.348>.
- Cykert, S., & Phifer, N. (2003). Surgical decisions for early stage, non-small cell lung cancer: Which racially sensitive perceptions of cancer are likely to explain racial variation in surgery? *Medical Decision Making: An International Journal of the Society for Medical Decision Making, 23*(2), 167–176. <https://doi.org/10.1177/0272989X03251244>.
- Delmerico, J., Hyland, A., Celestino, P., Reid, M., & Cummings, K. (2014). Patient willingness and barriers to receiving a CT scan for lung cancer screening. *Lung Cancer (Amsterdam, Netherlands), 84*(3), 307–309. <https://doi.org/10.1016/J.LUNG CAN.2014.03.003>.
- DeSantis, C., Jemal, A., & Ward, E. (2010). Disparities in breast cancer prognostic factors by race, insurance status, and education. *Cancer Causes & Control: CCC, 21*(9), 1445–1450. <https://doi.org/10.1007/S10552-010-9572-Z>.
- Deyo, R., Cherkin, D., & Ciol, M. (1992). Adapting a clinical comorbidity index for use with ICD-9-CM administrative databases. *Journal of Clinical Epidemiology, 45*(6), 613–619. [https://doi.org/10.1016/0895-4356\(92\)90133-8](https://doi.org/10.1016/0895-4356(92)90133-8).
- Farjah, F., Wood, D., Yanez, N., Vaughan, T., Symons, R., Krishnadasan, B., & Flu, D. (2009). Racial disparities among patients with lung cancer who were recommended

- operative therapy. *Archives of Surgery (Chicago, Ill.: 1960)*, 144(1), 14–18. <https://doi.org/10.1001/ARCHSURG.2008.519>.
- Feinglass, J., Rydzewski, N., & Yang, A. (2015). The socioeconomic gradient in all-cause mortality for women with breast cancer: findings from the 1998 to 2006 National Cancer Data Base with follow-up through 2011. *Annals of Epidemiology*, 25(8), 549–555. <https://doi.org/10.1016/J.ANNEPIDEM.2015.02.006>.
- Golecha, R., Eskender, M., Odell, D., & Feinglass, J. (2021). Racial and ethnic disparities in Illinois lung cancer incidence, mortality stage at diagnosis, surgical treatment, and screening. *Journal of Health Disparities Research and Practice*, 14(1). <https://digital.scholarship.unlv.edu/jhdrp/vol14/iss1/2>.
- Gordon, H., Street, R., Sharf, B., Kelly, P., & Soucek, J. (2006). Racial differences in trust and lung cancer patients' perceptions of physician communication. *Journal of Clinical Oncology: Official Journal of the American Society of Clinical Oncology*, 24(6), 904–909. <https://doi.org/10.1200/JCO.2005.03.1955>.
- Gumpertz, M., Pickle, L., Miller, B., & Bell, B. (2006). Geographic patterns of advanced breast cancer in Los Angeles: Associations with biological and sociodemographic factors (United States). *Cancer Causes & Control: CCC*, 17(3), 325–339. <https://doi.org/10.1007/S10552-005-0513-1>.
- Haiman, C., Stram, D., Wilkens, L., Pike, M., Kolonel, L., Henderson, B., & Le Marchand, L. (2006). Ethnic and racial differences in the smoking-related risk of lung cancer. *The New England Journal of Medicine*, 354(4), 333–342. <https://doi.org/10.1056/NEJMOA033250>.
- Harris, K. M., Majmundar, M. K., & Becker, T. (Eds.) (2021). *High and rising mortality rates among working-age adults*. Washington DC: The National Academies Press <https://doi.org/10.17226/25976>.
- Hayanga, A. J., Zeliadt, S. B., & Backhus, L. M. (2013). Residential segregation and lung cancer mortality in the United States. *JAMA Surgery*, 148(1), 37–42. <https://doi.org/10.1001/JAMASURGERY.2013.408>.
- Hittner, E., & Adam, E. (2020). Emotional pathways to the biological embodiment of racial discrimination experiences. *Psychosomatic Medicine*, 82(4), 420–431. <https://doi.org/10.1097/PSY.0000000000000792>.
- Howlander, N., Noone, A., & Krapcho, M. (2019). *Cancer Statistics Review, 1975–2016 – SEER Statistics*. [https://seer.cancer.gov/archive/csr/1975\\_2016/](https://seer.cancer.gov/archive/csr/1975_2016/).
- Japuntich, S., Krieger, N., Salvas, A., & Carey, M. (2018). Racial disparities in lung cancer screening: An exploratory investigation. *Journal of the National Medical Association*, 110(5), 424–427. <https://doi.org/10.1016/J.JNMA.2017.09.003>.
- Jones, N., Gilman, S., Cheng, T., Drury, S., Hill, C., & Geronimus, A. (2019). Life course approaches to the causes of health disparities. *American Journal of Public Health*, 109(S1), S48–S55. <https://doi.org/10.2105/AJPH.2018.304738>.

- Kawachi, I., Daniels, N., & Robinson, D. (2005). Health disparities by race and class: Why both matter. *Health Affairs (Project Hope)*, 24(2), 343–352. <https://doi.org/10.1377/HLTHAFF.24.2.343>.
- Krieger, N. (2019). Theoretical frameworks and cancer inequities. In Vaccarella S., Lortet-Tieulent, J., Saracci, R., Conway, D. I., Straif, K., & Wild, C. P. (Eds.), *Reducing social inequalities in cancer: evidence and priorities for research* (pp. 111–120). Lyon: International Agency for Research on Cancer.
- Krieger, N., Chen, J., Kosheleva, A., & Waterman, P. (2012). Shrinking, widening, reversing, and stagnating trends in US socioeconomic inequities in cancer mortality for the total, black, and white populations: 1960–2006. *Cancer Causes & Control: CCC*, 23(2), 297–319. <https://doi.org/10.1007/S10552-011-9879-4>.
- Krieger, N. (2013). History, Biology, and Health Inequities: Emergent Embodied Phenotypes and the Illustrative Case of the Breast Cancer Estrogen Receptor. *American Journal of Public Health*, 103(1), 22–27. <https://doi.org/10.2105/AJPH.2012.300967>.
- Krieger, N., Chen, J. T., & Waterman, P. D. (2010). Decline in US breast cancer rates after the Women's Health Initiative: Socioeconomic and racial/ethnic differentials. *American Journal of Public Health*, 100(Suppl 1), S132. <https://doi.org/10.2105/AJPH.2009.181628>.
- Krieger, N., Chen, J. T., & Waterman, P. D. (2011). Temporal trends in the black/white breast cancer case ratio for estrogen receptor status: disparities are historically contingent, not innate. *Cancer Causes & Control: CCC*, 22(3), 511. <https://doi.org/10.1007/S10552-010-9710-7>.
- Li, Z., Luo, L., Hu, Y., Chen, H., Den, Y., Tang, L., Liu, B., Liu, D., & Zhang, X. (2016). Lung cancer screening: a systematic review of clinical practice guidelines. *International Journal of Clinical Practice*, 70(1), 20–30. <https://doi.org/10.1111/IJCP.12744>.
- Margolis, M., Christie, J., Silvestri, G., Kaiser, L., Santiago, S., & Hansen-Flaschen, J. (2003). Racial differences pertaining to a belief about lung cancer surgery: results of a multicenter survey. *Annals of Internal Medicine*, 139(7). <https://doi.org/10.7326/0003-4819-139-7-200310070-00007>.
- McCartney, G., Bartley, M., Dundas, R., Katikireddi, S. V., Mitchell, R., Popham, F., Walsh, D., & Wami, W. (2019). Theorising social class and its application to the study of health inequalities. *SSM – Population Health*, 7, 100315. <https://doi.org/10.1016/J.SSMPH.2018.10.015>.
- McDade, T. W., & Harris, K. M. (2018). The biosocial approach to human development, Behavior, and health across the life course. *The Russell Sage Foundation Journal of the Social Sciences: RSF*, 4(4), 2. <https://doi.org/10.7758/RSF.2018.4.4.01>.
- Miller, K., Goding Sauer, A., Ortiz, A. P., Fedewa, S. A., Pinheiro, P. S., Tortolero-Luna, G., Martinez-Tyson, D., Jemal, A., & Siegel, R. L. (2018). Cancer Statistics for Hispanics/

- Latinos, 2018. *CA: A Cancer Journal for Clinicians*, 68(6), 425–445. <https://doi.org/10.3322/CAAC.21494>.
- Mulligan, C., Meram, A., Proctor, C., Wu, H., Zhu, K., & Marrogi, A. (2006). Unlimited access to care: effect on racial disparity and prognostic factors in lung cancer. *Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology*, 15(1), 25–31. <https://doi.org/10.1158/1055-9965.EPI-05-0537>.
- National Cancer Institute. (2014). *Cancer statistics review, 1975–2011 – previous version – SEER Cancer statistics review*. (n.d.). Retrieved August 25, 2021, from [https://seer.cancer.gov/archive/csr/1975\\_2011/](https://seer.cancer.gov/archive/csr/1975_2011/).
- O’Keefe, E. B., Meltzer, J. P., & Bethea, T. N. (2015). Health disparities and cancer: Racial disparities in cancer mortality in the United States, 2000–2010. *Frontiers in Public Health*, 3(51): 1–15. <https://doi.org/10.3389/FPUBH.2015.00051>.
- Richards, T. B. (2020). Screening for lung cancer – 10 states, 2017. *MMWR. Morbidity and Mortality Weekly Report*, 69(8), 201–206. <https://doi.org/10.15585/MMWR.MM6908A1>.
- Robert, S., Strombom, I., Trentham-Dietz, A., Hampton, J., McElroy, J., Newcomb, P., & Remington, P. (2004). Socioeconomic risk factors for breast cancer: Distinguishing individual- and community-level effects. *Epidemiology (Cambridge, Mass.)*, 15(4), 442–450. <https://doi.org/10.1097/01.EDE.0000129512.61698.03>.
- Ryan, B. (2018). Lung cancer health disparities. *Carcinogenesis*, 39(6), 741–751. <https://doi.org/10.1093/CARCIN/BGY047>.
- Surveillance, Epidemiology, and End Results (SEER) Program. *SEER\*Stat Database: Incidence-Based Mortality – SEER 18 Regs (Excl Louisiana) Research Data, Nov 2018 Sub (2000–2016) <Katrina/Rita Population Adjustment> – Linked To County Attributes – Total U.S., 1969–2017 Counties*. National Cancer Institute, DCCPS, Su. (n.d.). Retrieved August 25, 2021, from <https://seer.cancer.gov/data/hurricane.html>.
- Shavers, V., & Brown, M. (2002). Racial and ethnic disparities in the receipt of cancer treatment. *Journal of the National Cancer Institute*, 94(5), 334–357. <https://doi.org/10.1093/JNCI/94.5.334>.
- Siegel, R. L., Miller, K. D., Jemal, A. (2020). Cancer statistics, 2020. *CA: A Cancer Journal for Clinicians*, 70(1), 7–30. <https://doi.org/10.3322/CAAC.21590>.
- Soneji, S., Beltrán-Sánchez, H., & Sox, H. (2014). Assessing progress in reducing the burden of cancer mortality, 1985–2005. *Journal of Clinical Oncology: Official Journal of the American Society of Clinical Oncology*, 32(5), 444–448. <https://doi.org/10.1200/JCO.2013.50.8952>.
- Soneji, S., Tanner, N., Silvestri, G., Lathan, C., & Black, W. (2017). Racial and ethnic disparities in early-stage lung cancer survival. *Chest*, 152(3), 587–597. <https://doi.org/10.1016/J.CHEST.2017.03.059>.

- Stellman, J., & Stellman, S. (1996). Cancer and the workplace. *CA: A Cancer Journal for Clinicians*, 46(2), 1984–1988. <https://doi.org/10.3322/CANJCLIN.46.2.70>.
- Trinidad, D. R., Pérez-Stable, E. J., Messer, K., White, M. M., & Pierce, J. P. (2010). Menthol cigarettes and smoking cessation among racial/ethnic groups in the United States. *Addiction (Abingdon, England)*, 105(0 1), 84. <https://doi.org/10.1111/J.1360-0443.2010.03187.X>.
- Underwood, J., Townsend, J., Tai, E., Davis, S., Stewart, S., White, A., Momin, B., & Fairley, T. (2012). Racial and regional disparities in lung cancer incidence. *Cancer*, 118(7), 1910–1918. <https://doi.org/10.1002/CNCR.26479>.
- Velasco-Mondragon, E., Jimenez, A., Palladino-Davis, A., Davis, D., & Escamilla-Cejudo, J. (2016). Hispanic health in the USA: A scoping review of the literature. *Public Health Reviews*, 37(1). <https://doi.org/10.1186/S40985-016-0043-2>.
- Zimmerman, F. J., & Anderson, N. W. (2019). Trends in health equity in the United States by race/ethnicity, sex, and income, 1993–2017. *JAMA Network Open*, 2(6), e196386–e196386. <https://doi.org/10.1001/JAMANETWORKOPEN.2019.6386>.



# Reducing Cancer Mortality: A Cluster Analysis of Risk Factors for Lung Cancer across EU Countries

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## Abstract

This chapter compares risk factors for lung cancer and their significance for 27 countries in the European Union (EU). Drawing on data from a variety of sources, this study uses K-mean cluster analysis to investigate potentially modifiable risk factors for cancer including tobacco use, alcohol consumption, air pollution, socioeconomic status, and public expenditures on health care and their effects on lung cancer outcomes. Findings from this study show that the EU is not homogenous in terms of the effect of risk factors for lung cancer. Study results yielded four country groups, each representing different patterns in risk factors for lung cancer. The lowest rates of lung cancer mortality occur among southern European countries that includes: Italy, Spain, Portugal, Malta, and Romania. These countries present with a pattern of risk factors that include: relatively low alcohol consumption and low rates of smoking coupled with moderate population exposure to air pollutants. By contrast, another cluster of countries with the highest relative lung cancer rates includes Bulgaria, Cyprus, Greece, Croatia, Hungary and Poland. Here, rates of smoking and exposure to air pollutants are highest from among all the population groups analyzed, potentially lending a signal that these risk factors for lung cancer are most significant for this country group. Surprisingly, EU countries with the highest development levels and the highest ratio of health care spending relative to GDP, also present with a relatively high indicator of lung cancer mortality despite their relatively low rates of smoking and exposure to air pollutants. The heterogeneity among EU Member states regarding significant risk factors for lung cancer implies that cancer prevention policy needs to be tailored to individual patterns in risk factors for cancer.

## Keywords

lung cancer – cancer prevention – European Union – cluster analysis

## 1 Introduction

According to the World Health Organization (WHO), cancer ranks as a leading cause of death. In 2020, about 10.0 million cancer deaths were recorded, and 19.3 million new cancer cases were diagnosed worldwide. The global cancer burden is expected to grow rapidly reaching 28.4 million cases in 2040, a 47 percent rise when compared to the respective actual number of cases recorded for 2020. Lung cancer is one of the most commonly diagnosed types of cancer with a 11.4 percent share among the total number of new cancer cases diagnosed in 2020 (Sung et al., 2021). The highest lung cancer rates are reported in North America, Europe, and East Asia – particularly in China. In contrast, growth rates in new lung cancer cases are somewhat lower in Africa and South Asia (Mustafa et al., 2016). Nevertheless, lung cancer remains a leading cause of cancer death, resulting in nearly 1.8 million deaths worldwide or an 18 percent share of total cancer-related deaths in 2019 (Sung et al., 2021). These statistics are discouraging and call for continued research on the causes of cancer and possible ways to prevent it.

Many studies have shown that cancer might be preventable and that key risk factors for cancer are behavioral rather than related to genetic origin. These risk factors for cancer include but are not limited to: substance use and abuse, poor diet and nutrition, physical inactivity, body shape and exposure to air pollutants. Over 30–40 percent of cancer cases could be prevented through healthier lifestyles (Hofmarcher et al., 2019). Epidemiological and experimental studies further confirm that cancer incidence could be reduced through regulation of potentially controllable external factors, including environmental pollution. (Homaei Shandiz & Hadizadeh Talasaz, 2017; Turner et al., 2020). Furthermore, previous research shows that economic and social status, as measured by personal income and educational attainment, may have indirect effects on cancer incidence (Hemminki, & Li, 2003; Polak et al., 2019; Majcherek, Weresa & Ciecierski, 2020; 2021).

The motivation for this study derives from the context outlined above and aims to investigate the importance of lung-related cancer risk factors on cancer incidence in Europe while seeking out implications for cancer prevention policy for the EU. This chapter is structured as follows: Section 2 outlines recent literature regarding risk factors for cancer with the focus on lung cancer incidence. Section 3 describes the methodology used in this study. Section 4 presents the results, and Section 5 provides a discussion of the results and conclusions.

## 2 Lung Cancer Risk Factors – A Literature Review

Lung cancer occurs due to changes in the cells of the lungs, which grow and spread in an uncontrolled manner. This has many possible causes. Previous literature concerning risk factors for lung cancer suggests that lung cancer incidence depends on a variety of behavioral factors, such as tobacco use, poor diet and nutrition, alcohol consumption, exposure to air pollutants as well as other occupational factors (Bilello et al., 2002; Alberg & Samet, 2003; Malhotra et al., 2013; Mustafa et al., 2016). Most studies agree that cigarette use is the leading cause of both lung cancer incidence and death due to lung cancer (Alberg & Samet, 2003, Callagan et al., 2013; Kamis et al., 2021). The risk of lung cancer is estimated to be 20–40 times higher for smokers when compared to non-smokers (Ozlu & Bülbül, 2005; Walser et al., 2008; Krawczyk et al., 2021). Estimates from the International Agency for Research on Cancer (IARC) Risk Assessment suggest that smoking claims approximately 1.5 million deaths from lung cancer worldwide (Proctor, 2011). A review of epidemiological and experimental studies from eight different countries confirms this strong association between smoking behavior and lung cancer (Cornfield, 2009). The risk of developing lung cancer increases with both the duration of smoking as well as the frequency of use and the quantity of cigarettes smoked yet falls with the number of years since smoking cessation (Cornfield, 2009; Fukuda et al., 2018; Park et al., 2020). Gender differences prevail as men exhibit a higher incidence of lung cancer when compared to their female counterparts (Park et al., 2020). Although tobacco use is a major risk factor for developing lung cancer, studies also show that about one fourth of all lung cancer cases occur among patients who never smoked (Fukuda et al., 2018).<sup>1</sup>

Another health-related behavior that contributes to lung cancer incidence is alcohol consumption (Troche et al., 2015). An appreciable number of case control and cohort studies have evaluated the impact of alcohol use on lung cancer incidence. Bandera et al. (2001) provide a review of the epidemiological evidence published between 1984 and 2000 on this topic. The authors conclude that upon controlling for smoking behavior, consumption of all forms of alcoholic beverages and particularly, beer, may increase the risk of lung cancer incidence.

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1 Fukuda et al. (2018) explain that increases in cancer incidence among non-smokers is due to two mutations: one, in the epidermal growth factor receptor gene (EGFR) while the other is a chromosomal rearrangement involving the anaplastic lymphoma kinase gene (ALK). Unfortunately, regardless of smoking status, the etiologies of these in regards to lung cancer remain unknown.

Risk factors for lung cancer frequently analyzed together in the epidemiological literature include: diet, sports activity and body weight. Alberg and Samet (2003) as well as Malhotra et al. (2016) reference evidence from a variety of case-control studies that confirm a protective effect of a diet rich in fruits and vegetables, and in particular, those containing carotenoids, against lung cancer. Surprisingly, obesity was also found to have some protective effect against lung cancer (Yang et al., 2012), despite obesity being recognized as a risk factor for thirteen other types of cancer (Calle et al., 2003). A meta-analysis of 31 papers on the relationship between obesity and lung cancer incidence reveals that overweight and obesity were inversely associated with lung cancer occurrence, suggesting a protective role of such risk factors against lung cancer in current and former smokers (Yang et al., 2012). In turn, a study by Patel et al. (2017) and their analysis of a cohort of US adults confirmed no association between obesity (as measured by Body Mass Index, BMI) and waist circumference with lung cancer regardless of smoking status. In this study, a similar conclusion was also formulated regarding the role of physical activity in protecting against lung cancer. Other studies find positive relationships between physical activity and reduced rates of lung cancer. When comparing lung cancer incidence among individuals reporting appreciable sports activity with respondents in the low or absent category of sports activity, Patel et al. (2019) find moderate protective effects of sports activity against lung cancer, possibly confirming, that minimizing time spent in sedentary behavior may play some role. In this study, protective associations were revealed for both lung cancer incidence and mortality in relation to physical exercise in older women, with this association being particularly stronger for women who were not obese (Wang et al., 2016). Another study by Zhong et al. (2016), covers twelve cohorts and six case-control studies involving nearly 2.5 million participants and over 26 thousand lung cancer cases also confirms protective effects of physical activity against lung cancer. McTiernan et al. (2019), in their systematic literature review on cancer prevention, quote the results from the 2018 Physical Activity Guidelines Advisory Committee of the United States Department of Health and Human Services (USDHHS) which, based on a comprehensive meta-analysis, concludes that high levels of physical activity result in a 25 percent relative reduction in lung cancer risk.

Air pollution is another important risk factor for lung cancer (e.g. Alberg & Samet, 2003; Mao et al., 2016; Kamis et al., 2021; Krawczyk et al., 2021). According to the World Cancer Report from the WHO, exposure to air pollution deriving from various sources, (e.g. industrial pollution, diesel engine exhaust, households use of solid fuels) increases the likelihood of developing lung cancer. Key air pollutants include particulate matter, ambient ozone, carbon monoxide (CO), hydrocarbons, sulphur and nitrogen oxides, benzene, and certain metals

(Pb, As, Cd, Ni). In 2017, air pollutants were estimated to cause over 350 thousand deaths due to lung cancer worldwide (Wild, Steward, eds., 2020, p. 116). Kamis et al., (2021) analyze key ambient emissions across the US and their association with lung cancer. Using a variety of regression models, the authors find that  $PM_{2.5}$ , CO, sulfur dioxide, and ozone were the most hazardous over multiple timeframes. Moreover, comparative evaluation of different outdoor air pollutants and their carcinogenic hazard for lung cancer worldwide showed that particulate matter (PM) is a key agent among air pollutants causing deaths due to lung cancer (Wild, Steward, eds., 2020, p. 117). Epidemiological studies have confirmed this finding for other countries. For example, one study uses individual data from seventeen European cohorts covering over three hundred thousand members to confirm statistically significant but small association between long-term exposure to  $PM_{10}$  and the risk for lung cancer (Raaschou-Nielsen et al., 2013).

Hajat et al. (2021) observe that socioeconomic status (SES) may be an important modifier of the impact of air pollutants on health, including cancer, and provides a wide overview of variables used to measure SES, income, educational attainment and occupational status. This detailed research on social status and how it relates to lung cancer stresses the importance of local context in identifying patterns of lung cancer risk, which may help define potential targets of intervention regarding a more complete spectrum of risk factors for cancer (Williams et al., 2012). Similar conclusions and policy implications derive from another study, which focuses on specific profiles of lung cancer in countries or country groups broken down by development levels and measured by the Human Development Index (HDI). Inclusion of SES into this analysis allows for the identification of new opportunities to reduce the burden of lung cancer by adjusting prevention to the specific profile of country/regional risk factors for cancer (Cheng et al., 2016).

Finally, Danaei et al. (2005) offer a comprehensive study focused on a comparative assessment of nine risk factors for twelve different types of cancer across a variety of regions further categorized by income levels. Estimation of population attributable fractions for lung cancer reveal that worldwide, 70 percent of risk factors for cancer can be attributed to smoking, 11 percent to low fruit and vegetable intake, 5 percent to exposure to air pollutants with the remaining percentage ascribed to other factors (Danaei et al., 2005). The study by Danaei et al. (2005) also reveals that the role of risk factors for lung cancer differ across regions of the world economy when broken down by income levels. For example, the percentage attributed to smoking behavior as a risk factor for lung cancer was higher (86 percent) for high-income countries when compared to low and middle-income counterparts (60 percent) (Danaei et al., 2005, p. 1787). These findings suggest that the significance of individual-level

risk factors for cancer is country-specific. Study results also reveal that risk factors for cancer are related to the SES of society.

Results from this literature review are in-line with the objective of this chapter, which aims to identify differences among EU countries regarding the role of risk factors in developing lung cancer. Differences as well as similarities among countries constitute a basis for clustering EU countries into similar groups, thus allowing this analysis to arrive at implications for policies seeking to curb cancer burden.

### 3 Methodology

Country-level cluster analysis was performed using data derived from the following sources:

- Lung cancer mortality
  - Lung cancer deaths taken from the 2017 Global Burden of Disease Study (Institute for Health Metrics and Evaluation (IHME), 2018) (variable name: Lung mortality, data from 2015).
- Socioeconomic status (SES):
  - GDP per capita in EUR extracted from Eurostat (Eurostat, 2020b) (variable name: GDP/capita, data from 2015).
  - Educational attainment was drawn from the UNESCO Institute for Statistics (UIS) (The UNESCO Institute for Statistics (UIS), 2020) (variable name: Years of Edu, data from 2015).
  - General domestic government health expenditure as a percentage of Gross Domestic Product (GDP) (%) derives from World Health Organization (WHO) (World Health Organization, 2020a) (variable name: health-care (HC) spending, data from 2015).
- Alcohol consumption:
  - Alcohol consumption in liters for the same calendar year from WHO (Division of Information, Evidence, Research and Innovation & WHO Regional Office for Europe, World Health Organization, 2020) (variable name: alcohol, data from 2014).
- Tobacco use:
  - The percentage of the population that smokes currently derives from the European Health Interview Survey (EHIS) (Eurostat, 2020a) (variable name: smoke, data from 2014).
- Diet and nutrition:
  - The fraction of the population that eats fruits or vegetables more than 5 times per week was also taken from the EHIS (Eurostat, 2020a) (variable name: diet, data from 2014).

- Body mass index (BMI):
  - The fraction of the population with a Body Mass Index (BMI) equal or greater than 30 was also extracted from the EHIS data (Eurostat, 2020a) (variable name: obese, data from 2014).
  - The percentage of the population with membership in a sports club comes from Eurobarometer (European Union, 2014) (variable name: sports club membership (SC), data from 2013)
  - The ratio of the population which exercises or plays sports at least once per week. This data was taken from the Eurobarometer (European Union, 2014) (variable name: sports activity (SA), data from 2013)
- Air pollutant measure:
  - Information on particulate matter derives from the European Environment Agency (EEA) (European Environment Agency, 2018) and includes  $PM_{10}$ , which captures the presence of inhalable particles, with diameters that are generally 10 micrometers and smaller (variable name:  $PM_{10}$ days – number of days when  $PM_{10}$  exceeds  $50 \mu g/m^3$ )

The cluster analysis was conducted for 27 European Union (EU) countries including: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Germany, Denmark, Estonia, Greece, Spain, Finland, France, Croatia, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, the Netherlands, Poland, Portugal, Romania, Sweden, Slovenia, and Slovakia. The analysis covers risk factors related to consumer health behaviors, air pollutants, and socioeconomic status (Hartigan & Wong, 1979). In order to limit the potentially large effect of variable variance on results, a standardization of variables was performed. The goal of this analysis is to identify groups of countries that are as similar as possible with regards to their respective risk factors for lung cancer mortality. Given earlier studies, there is a simple decision criteria available for selecting the proper number of clusters (Caruso et al., 2019; Henry et al., 2015; Ketchen & Shook, 1996). This is a multi-decision problem and additional algorithms must be developed in order to automatically resolve this issue. We empirically determined that the 4-cluster solution yielded the best match because with this split, all clusters were disjoint sets and empirical interpretation was reasonable. The cluster analysis was conducted using R (R Core Team, 2019) and the CRAN factoextra package (Kassambara & Mundt, 2020).

## 4 Results

Figure 2.1 and Table 2.1 provide results of the cluster analysis. The merged dataset containing information regarding lung cancer mortality, SES, various

health-related behaviors and air pollutants allows for four distinguished clusters from across EU countries:

- Cluster I (5 countries): Spain, Italy, Malta, Portugal, Romania;
- Cluster II (6 countries): Bulgaria, Cyprus, Greece, Croatia, Hungary, Poland;
- Cluster III (10 countries): Germany, Austria, France, Belgium, the Netherlands, Luxembourg, Denmark, Finland, Sweden, and Ireland;
- Cluster IV (6 countries): the Czech Republic, Slovakia, Estonia, Lithuania, Latvia, and Slovenia.

Cluster I envelopes countries with the lowest rates of lung cancer deaths per 100,000 inhabitants (i.e., as shown in Table 2.A1 in the Annex, 41 deaths/100,000 in Portugal and Malta, and up to 59 deaths/100,000 in Italy) and differs most from other countries with respect to lifestyle measures. This cluster is characterized by the lowest levels of alcohol consumption across all cluster ranges, from 7.14 liters per capita in Italy to as high as 10.54 liters in Portugal. Moreover, low smoking rates prevail among countries in this cluster (i.e., from 6 percent in Portugal to 11 percent in Italy) with an overall average of only 14 percent of the adult population in Cluster I reporting smoking. However, Cluster I also captures countries with the lowest rates of fruit and vegetable intake (i.e., from

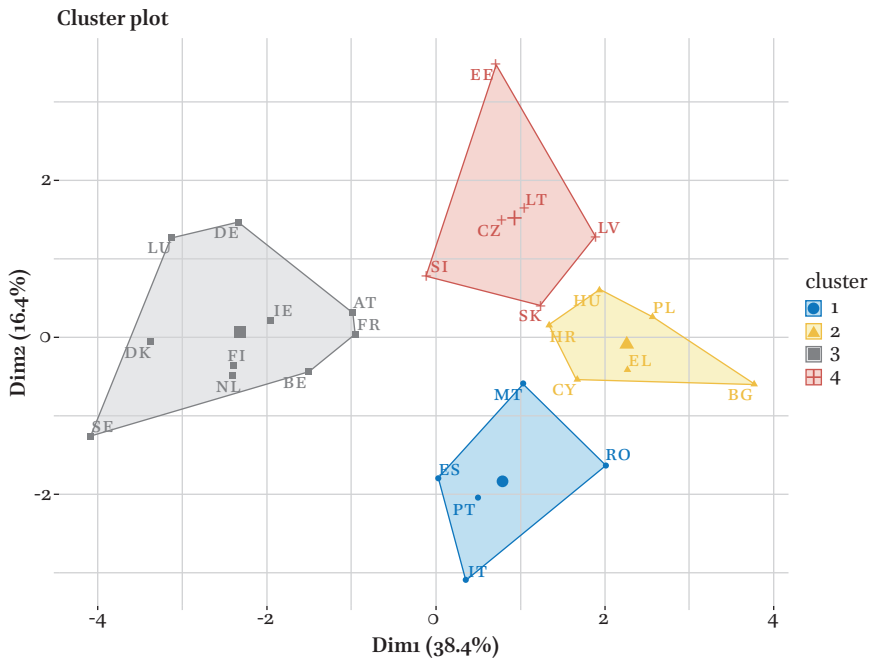


FIGURE 2.1 Cluster plot for 11 indicators of lung cancer mortality across 27 countries  
SOURCE: AUTHORS' ELABORATION



TABLE 2.1 Cluster means for 11 indications and lung cancer mortality

Cluster	Lung mortality (per 100,000)	GDP/capita [EUR]	HC spending (%)	Years of education	PM <sub>10</sub> days	
1	48.58	19,508.00	5.72	10.29	17.28	
2	67.46	12,826.67	4.40	11.84	43.28	
3	54.48	46,807.00	7.47	12.47	7.84	
4	50.11	15,090.00	5.00	13.03	19.64	
Cluster	Alcohol [liters]	Smoke [%]	Diet [%]	Obese [%]	Sports club [%]	Sports activity [%]
1	8.82	13.80	9.80	15.42	0.05	0.29
2	10.45	25.17	16.67	16.75	0.05	0.30
3	10.15	11.40	16.50	15.09	0.20	0.55
4	12.83	23.00	16.00	18.38	0.09	0.38

Note: Lung mortality is lung cancer mortality per 100,000 inhabitants; GDP is Gross Domestic Product; HC spending is Public Healthcare expenditures as a percentage of GDP; PM<sub>10</sub> represents Particulate Matter with a diameter between 2.5 µm and 10 µm.

SOURCE: AUTHORS' ELABORATION

1 percent in Romania, up to 18 percent in Portugal). In addition, Cluster 1 is characterized by the lowest rates of sports activity (SA) (i.e., 19 percent in Malta up to 46 percent in Spain) and the lowest occurrence of sports club (SC) membership (i.e., from a low of 1 percent in Romania to a high of 7 percent in Spain and Italy). Finally, Cluster 1 includes countries with the low levels of reported obesity from across all cluster ranges (i.e., 9.1 percent in Romania to 10.5 percent in Italy). Although this cluster is characterized by populations with the lowest average number of years of education completed (i.e. an overall cluster average of ten years) it also envelopes those that rank second highest in terms of GDP per capita (i.e., approximately 19 500 EUR) and rates of expenditure on public health care (HC) (i.e., 5.72 percent of GDP). In addition, Cluster 1 is characterized by the second lowest levels of air pollutants present (PM<sub>10</sub>days) (i.e., an approximate 10 days per year when PM<sub>10</sub> exceeds 50 µg/m<sup>3</sup> in both Portugal and Spain).

Cluster II includes countries with the highest rates of lung cancer deaths per 100,000 inhabitants (i.e., from 47 deaths/100,000 in Cyprus to 93 deaths/100,000 in Hungary) and captures populations with an array of varying consumer health behaviors that distinguish this cluster from the rest. First, Cluster II includes countries with the highest possible smoking rates (i.e. 21 percent in Poland to a high of 31 percent in Bulgaria), the second highest levels of alcohol consumption (11 liters per year in Bulgaria and Hungary), the second highest in terms of adult obesity (i.e. with Hungary and Croatia reporting highest rates of obesity) and the second lowest in terms of participation in sports activity and membership in sports clubs (i.e. Bulgaria and Poland report the lowest rates of participation in both). Only 3 percent of citizens in Hungary and Poland declare eating fruits or vegetables more than 5 times weekly. SES status is low in Cluster II as it includes countries with lowest levels of GDP per capita (i.e., from 6360 EUR in Bulgaria to as high as 21 030 EUR in Cyprus), presents with the lowest fraction of public expenditure spent on health care (i.e., 4.4 percent of GDP) and captures a population with the second lowest number of years of education completed (an average of approximately 12 years). In Cluster II the air pollutant indicator is among the highest and measures approximately 43 days per year when  $PM_{10}$  exceeds  $50 \mu\text{g}/\text{m}^3$  (i.e. ranges from 29 days in Hungary to as high as 64 days in Bulgaria).

Among countries belonging to Cluster III, lung cancer deaths per 100,000 inhabitants are second highest from across all European countries included in this analysis (i.e., from 41 deaths/100,000 in Sweden, Finland and Ireland to 70 deaths/100,000 in Denmark and the Netherlands). This cluster is dominated by characteristics representing high SES. Although the average number of completed years of education is approximately only 13, GDP per capita is high and measures 46,807 EUR per year, an average that is almost fourth times greater than reported for Clusters I and II, and three times the amount reported in Cluster IV. In addition, the ratio of public expenditures on health care is around 7.5 percent of GDP which is also highest among all clusters. Moreover, the variable  $PM_{10}$ days, the air pollutant indicator, is lowest among clusters and amounts to only 8 days when yearly when  $PM_{10}$  exceeds  $50 \mu\text{g}/\text{m}^3$ . Health-related behaviors vary significantly within this cluster. For example, medium-ranked levels of alcohol consumption across the clusters range from 7.16 liters in Sweden to as high as 11.99 liters in Germany. Smoking rates are lowest in Sweden (one percent) and highest in France (25 percent).

While the measure for fruit and vegetable intake ranks moderately for this cluster (i.e., from 2 percent in Germany, up to 30 percent in Sweden), the number of obesity-related lung cancer deaths is lowest in Cluster III (i.e., from a

low of 13 percent in the Netherlands and Sweden to a high of only 18 percent in Ireland and Finland). Cluster III also includes countries with the highest level of sports activity (i.e. from 43 percent in France to a high of 70 percent in Sweden), and the highest engagement in sports club membership (i.e., from a low of 12 percent in Finland to a high of 27 percent in the Netherlands).

Cluster IV comprises of countries with the second lowest rates of lung cancer deaths per 100,000 inhabitants among all the groups studied. Here, lung cancer death rates range from 44 deaths/100,000 in Slovakia to 55 deaths/100,000 in Slovenia and the Czech Republic. This cluster is characterized by the lowest number of completed years of education, the highest percentage of obese in the population and the highest levels of reported alcohol consumption. Although the average number of completed years of education is relatively high (i.e., from a low of 12.6 in Slovenia to 13.9 years in Estonia) this cluster also encapsulates populations with the second lowest measures of annual GDP per capita (i.e., an average of approximately 15 090 EUR), the second lowest percentage of GDP dedicated to health care spending (i.e., measures at approximately 5 percent of GDP) and the second highest ranking measure of air pollutants ( $PM_{10}$  days) when compared to countries belonging to other clusters. Indeed, population-based health behaviors captured by Cluster IV differ significantly from those present in other clusters. The Cluster IV countries differ from other countries due to its relatively high alcohol consumption (i.e., ranges from 14.42 liters in Lithuania to 16.64 liters in Estonia), relatively high smoking rates (range from 14 percent in Slovenia to as high as 28 percent in Latvia), highest rates of obesity when compared to other resulting clusters (i.e., 20 percent in Estonia to almost 21 percent in Latvia) combined with a medium percentage of people who eat fruits or vegetables more than 5 times per week (i.e., from 4 percent in Slovakia to 31 percent in the Czech Republic). Finally, Cluster IV includes countries with high average ranges in sports activity participation (i.e., from 36 percent engagement in the Czech Republic to as much as 51 percent engagement in Slovenia), while membership in sports clubs is low and ranges from only 6 percent in Latvia to 12 percent in Estonia and Slovenia.

In addition to cluster analysis, a multiple regression model (Table 2.A2 in the Annex) was performed in order to understand the cause and effect relationship between lung cancer mortality and risk factors for cancer. Keeping in mind the significant limitations of such models, (only 30 regions used), the regression analysis shows the directional impact of the environment, lifestyle and SES on lung cancer mortality. The results are consistent with the literature. Smoking, alcohol consumption, obesity and air pollution may lead to an increase in lung cancer mortality, while higher levels of GDP per capita and

education seem to have a diminishing effect. However, only four risk factors in the regression model (i.e. air pollution, diet, sport activity and years of education) are statistically significant. Regression modelling is an ecological analysis, and interpretations of causality should be made with caution. As to correlation analysis, lung cancer mortality is positively related to smoking and air pollution ( $PM_{10}$ ) and negatively related to GDP per capita or diet.

## 5 Discussion and Conclusion

While risk factors for cancer are widely discussed and behavior changes have been identified as a means to protect against developing cancer, little has been written about the heterogeneity of countries regarding the importance of individual risk factors for lung cancer risk, particularly when considering economic development and education levels among individual countries. This chapter aims to fill this gap by providing new evidence about the importance of various risk factors for lung cancer mortality in EU countries. This analysis also includes country-specific contextual factors, such as socioeconomic status and level of education as well as public spending on health care as it relates to GDP. Using a k-means cluster approach, this study shows that the EU is not homogenous in terms of the impact of risk factors on lung cancer mortality (see Figure 2.2 below).

Cluster I countries (see Figure 2.1) are one of four country-groups identified in this study and together are characterized by the lowest rates of lung cancer deaths per 100,000 inhabitants. This cluster encompasses southern European countries (i.e., Italy, Spain, Portugal, Malta, and Romania), which enjoy relatively high standards of living as measured by GDP per capita as well as the percentage of the country's GDP appropriated for health care spending. Patterns in risk factors for cancer that dominate in these countries compared to other country groups can be described as relatively low smoking and drinking rates coupled with low exposure to air pollutants. Furthermore, these countries spend relatively high percentages of their GDP on healthcare. The simultaneous effects of this combination of factors may contribute to the lowest prevailing lung cancer mortality rates among the four defined EU country clusters.

At the other extreme, is Cluster II which groups together EU countries characterized by the highest lung cancer mortality rates (Bulgaria, Cyprus, Greece, Croatia, Hungary, Poland). When compared to the remaining three country clusters, cluster II countries present with low socioeconomic status and the lowest rates of expenditures on health care. The risk factors for cancer that

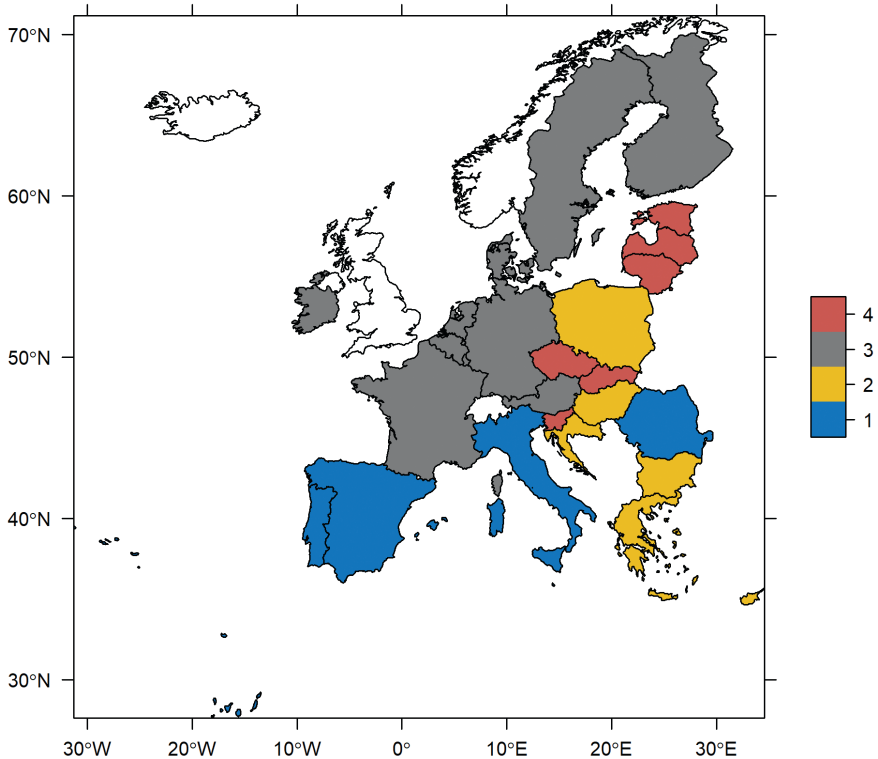


FIGURE 2.2 Lung cancer clustering results presented on the map of Europe  
SOURCE: AUTHORS' ELABORATION

prevail within this group include: relatively highest rates of exposure to air pollutants, the highest smoking rates, the second highest proportion of alcohol consumption, as well as a relatively low proportion of the population engaged in sports activity. Our study findings concerning Cluster I and Cluster II are in-line with the results reported by a vast number of existing epidemiological studies that stress tobacco smoking as a dominant risk factor for developing cancer (Danaei et al., 2005; Callagan et al., 2013; Kamis et al., 2021).

Surprisingly, results from this study show that the second highest lung cancer death rate occur among the most highly developed member states in the EU which enjoy the highest measures of socioeconomic status combined with relatively large public expenditures on health care. This group is captured by Cluster III and contains 10 western and northern European countries including: Germany, Austria, France, Belgium, Luxembourg, the Netherlands, Denmark, Finland, Sweden and Ireland. When compared to other clusters,

the smoking rate and the air pollutant indicator are both lowest for Cluster III while sports activity and diet (i.e. weekly intake of fruits and vegetables) are highest among clusters. Finally, the alcohol intake indicator in Cluster III is relatively high in value, although within the cluster, this measure varies considerably across countries. For example, in some countries states (e.g. Sweden) alcohol is a predominant risk factor for cancer, while in others (e.g. France) tobacco smoking appears to be more significant.

The remaining cluster of EU states form Cluster IV and include the Czech Republic, Slovakia, Estonia, Lithuania, Latvia, and Slovenia. Countries captured by this cluster present with the second lowest lung cancer mortality from among all four identified country groups. Cluster IV is characterized by low levels of GDP per capita and low ratios of expenditures on health care. While the measure for air pollutants is low, rates of alcohol consumption is highest when compared to other clusters. Smoking rates are also relatively high. These behavioral and environmental risk factors are likely compensated for by the moderate obesity rates, intensive sports activity (i.e. the second highest among country groups analyzed in this study) and moderate fruit and vegetable intake. Favorable health behavior outcomes among these countries play a protective role against lung cancer (Alberg and Samet, 2003; Malhotra et al., 2016), and particularly among current and former smokers (Yang et al., 2012). Nevertheless, the patterns in risk factors for lung cancer among these two EU country clusters (Cluster III and IV) cannot be easily explained by referencing results of epidemiological studies. Smoking was proved to be the most important risk factor for lung cancer incidence (Alberg, Samet, 2003, Danaei et al., 2005; Kamis et al., 2021). Moreover, the risk for cancer continues to grow as smoking duration, quantity smoked and frequency of smoking rises. By the same token, risk decreases when the number of years since smoking cessation increases (Cornfield, 2009; Fukuda et al., 2018; Park et al., 2020). Passive smoking is an important yet missing consideration for non-smokers. Indeed, the need for a more detailed analysis exists, and begs for such considerations to be included in the analysis before settling on a comprehensive risk assessment for these two groups of countries.

Extensions of this study could also entail inclusion of other environmental factors (e.g. asbestos, radiation) as well as measures of the prevalence of screening programs, and varying methods of lung cancer treatment. Nonetheless, as this study shows, socioeconomic status of the population and expenditures on health care may constitute critical modifiers of lung cancer mortality. Therefore, continuing to include SES in further research on risk factors for cancer may shed new and important light on collective impact.

This chapter highlights some of the differences regarding the importance of individual risk factors for lung cancer in EU countries. Chapter findings imply that it may be more beneficial to tailor cancer prevention policy to the behavioral and environmental patterns associated with each of the EU country clusters revealed in this chapter. From a public health perspective, diverse policy measures should be taken to more effectively decrease lung cancer incidence and mortality across the EU. A holistic, problem-oriented, target approach to public health policy, including policy aimed at curbing lung cancer burden specifically, should be considered. Targeting risk factors and designing public policy actions that influence lung cancer incidence in a directed fashion (i.e., tobacco and alcohol restrictions, tobacco and alcohol price policy through taxation, education about benefits and risks for personal health) might be most effective, particularly when policy is systemic, broad-based and tailored to specific patterns in risk factors for lung cancer as they pertain to groups of similar country populations and environments.

## References

- Alberg, A. J., & Samet, J. M. (2003). Epidemiology of lung cancer. *Chest*, 123(1), 21S–49S. [https://doi.org/10.1378/chest.123.1\\_suppl.21s](https://doi.org/10.1378/chest.123.1_suppl.21s).
- Bagnardi, V., Rota, M., Botteri, E., Scotti, L., Jenab, M., Bellocco, R., Tramacere, I., Pelucchi, C., Negri, E., La Vecchia, C., Corrao, G., & Boffetta, P. (2011). Alcohol consumption and lung cancer risk in never smokers: A meta-analysis. *Annals of Oncology*, 22(12), 2631–2639. <https://doi.org/10.1093/annonc/mdr027>.
- Bandera, E. V., Freudenheim, J. L., & Vena, J. E. (2001). Alcohol consumption and lung cancer: A review of the epidemiologic evidence. *Cancer Epidemiology, Biomarkers & Prevention*. A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, 10(8), 813–821.
- Billello, K. S., Murin, S., & Matthay, R. A. (2002). Epidemiology, etiology, and prevention of lung cancer. *Clinics in Chest Medicine*, 23(1), 1–25. [https://doi.org/10.1016/S0272-5231\(03\)00057-1](https://doi.org/10.1016/S0272-5231(03)00057-1).
- Callaghan, R. C., Allebeck, P., & Sidorchuk, A. (2013). Marijuana use and risk of lung cancer: A 40-year cohort study. *Cancer Causes & Control*, 24(10), 1811–1820. <https://doi.org/10.1007/s10552-013-0259-0>.
- Calle, E. E., Rodriguez, C., Walker-Thurmond, K., & Thun, M. J. (2003). Overweight, obesity, and mortality from cancer in a prospectively studied cohort of U.S. adults. *New England Journal of Medicine*, 348(17), 1625–1638. <https://doi.org/10.1056/nejmoa021423>.

- Caruso, G., Gattone, S. A., Balzanella, A., & Di Battista, T. (2019). Cluster analysis: An application to a real mixed-type data set. In C. Flaut, Š. Hořková-Mayerová, & D. Flaut (Eds.), *Models and Theories in Social Systems*, (pp. 525–533). Cham: Springer International Publishing. [https://doi.org/10.1007/978-3-030-00084-4\\_27](https://doi.org/10.1007/978-3-030-00084-4_27).
- Cheng, T.-Y. D., Cramb, S. M., Baade, P. D., Youlden, D. R., Nwogu, C., & Reid, M. E. (2016). The international epidemiology of lung cancer: Latest trends, disparities, and tumor characteristics. *Journal of Thoracic Oncology*, 11(10), 1653–1671. doi:10.1016/j.jtho.2016.05.021.
- Cornfield, J., Haenszel, W., Hammond, E. C., Lilienfeld, A. M., Shimkin, M. B., & Wynder, E. L. (2009). Smoking and lung cancer: Recent evidence and a discussion of some questions. *International Journal of Epidemiology*, 38(5), 1175–1191. <https://doi.org/10.1093/ije/dyp289>.
- Danaei, G., Vander Hoorn, S., Lopez, A. D., Murray, C. J., Ezzati, M., & Comparative Risk Assessment collaborating group (Cancers) (2005). Causes of cancer in the world: Comparative risk assessment of nine behavioural and environmental risk factors. *Lancet* (London, England), 366(9499), 1784–1793. [https://doi.org/10.1016/S0140-6736\(05\)67725-2](https://doi.org/10.1016/S0140-6736(05)67725-2).
- Division of Information, Evidence, Research and Innovation & WHO Regional Office for Europe, World Health Organization. (2020, August 26). [Dataset] *European Health for All database (HFA-DB)*. <https://gateway.euro.who.int/en/datasets/european-health-for-all-database/>.
- European Environment Agency. (2018). Air quality in Europe – 2018 [Publication]. European Environment Agency. <https://www.eea.europa.eu/publications/air-quality-in-europe-2018>.
- European Union. (2014). Special Eurobarometer 412 “Sport and physical activity” [Website]. Publications Office of the European Union. <http://op.europa.eu/en/publication-detail/-/publication/574742b9-4d66-4a3a-bced-a51ef3263846>.
- Eurostat. (2020a, August 26). [Dataset] *European Health Interview Survey (EHIS)*. [https://ec.europa.eu/eurostat/cache/metadata/en/hlth\\_det\\_esms.htm](https://ec.europa.eu/eurostat/cache/metadata/en/hlth_det_esms.htm).
- Eurostat. (2020b, August 26). [Dataset] *Main GDP aggregates per capita*. [https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama\\_10\\_pc&lang=en](https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_pc&lang=en).
- Fukuda, M., Mukae, H., & Ashizawa, K. (2017). Tobacco control and lung cancer. *Oncology Research and Reviews*, 1(1). <https://doi.org/10.15761/orr.1000106>.
- Hajat, A., MacLehose, R. F., Rosofsky, A., Walker, K. D., & Clougherty, J. E. (2021). Confounding by socioeconomic status in epidemiological studies of air pollution and health: Challenges and opportunities. *Environmental Health Perspectives*, 129(6), 065001. <https://doi.org/10.1289/ehp7980>.
- Hartigan, J. A., & Wong, M. A. (1979). Algorithm AS 136: A K-means clustering algorithm. *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, 28(1), 100–108. JSTOR. <https://doi.org/10.2307/2346830>.



- Hemminki, K., & Li, X. (2003). Level of education and the risk of cancer in Sweden. *Cancer Epidemiology, Biomarkers & Prevention*. A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology, 12(8), 796–802.
- Henry, D., Dymnicki, A. B., Mohatt, N., Allen, J., & Kelly, J. G. (2015). Clustering methods with qualitative data: A mixed methods approach for prevention research with small samples. *Prevention Science: The Official Journal of the Society for Prevention Research*, 16(7), 1007–1016. <https://doi.org/10.1007/s1121-015-0561-z>.
- Hofmarcher, T., Brådvik, G., Svedman, C., Lindgren, P., Jönsson, B., & Wilking, N. (2019). *Comparator Report on Cancer in Europe 2019*. Lund: IHE.
- Institute for Health Metrics and Evaluation (IHME). (2018). [dataset] *Global burden of disease collaborative network. Global burden of disease study 2017 (GBD 2017) cause-specific mortality 1980–2017*.
- Kamis, A., Cao, R., He, Y., Tian, Y., & Wu, C. (2021). Predicting lung cancer in the United States: A multiple model examination of public health factors. *International Journal of Environmental Research and Public Health*, 18(11), 6127. <https://doi.org/10.3390/ijerph18116127>.
- Kassambara, A., & Mundt, F. (2020). *Factoextra: Extract and visualize the results of multivariate data analyses (1.0.7) [Computer software]*. <https://CRAN.R-project.org/package=factoextra>.
- Ketchen, D. J., & Shook, C. L. (1996). The application of cluster analysis in strategic management research: An analysis and critique. *Strategic Management Journal*, 17(6), 441–458. JSTOR.
- Krawczyk, P., Ramlau, R., Błach, J., Kieszko, R., Roszkowski-Ślisz, K., Kucharczyk, T., Kieszko, S., & Milanowski, J. (2021) Risk factors and primary prevention of lung cancer. Cessation of cigarette addiction. *Oncology in Clinical Practice*, 17(3), 112–124. <https://doi.org/10.5603/OCP.2021.0011>.
- Majcherek, D., Weresa, M. A., & Ciecierski, C. (2020). Understanding regional risk factors for cancer: A cluster analysis of lifestyle, environment and socio-economic status in Poland. *Sustainability*, 12(21), 9080. <https://doi.org/10.3390/su12219080>.
- Majcherek, D., Weresa, M. A., & Ciecierski, C. (2021). A cluster analysis of risk factors for cancer across EU Countries: Health policy recommendations for prevention. *International Journal of Environmental Research and Public Health*, 18(15), 8142. <https://doi.org/10.3390/ijerph18158142>.
- McTiernan, A., Friedenreich, C. M., Katzmarzyk, P. T., Powell, K. E., Macko, R., Buchner, D., Pescatello, L. S., Bloodgood, B., Tennant, B., Vaux-Bjerke, A., George, S. M., Troiano, R. P., Piercy, K. L., & 2018 Physical Activity Guidelines Advisory Committee (2019). Physical activity in cancer prevention and survival: A systematic review. *Medicine and Science in Sports and Exercise*, 51(6), 1252–1261. <https://doi.org/10.1249/MSS.0000000000001937>.

- Mustafa, M., Azizi, A. R. J., Izzam, E. L., Nazirah, A., Sharifa, S., & Abbas, S. A. (2016). Lung cancer: Risk factors, management, and prognosis. *IOSR Journal of Dental and Medical Sciences*, *15*(10), 94–101. <https://doi.org/10.9790/0853-15100494101>.
- Ozlu, T., & Bülbul, Y. (2005). Smoking and lung cancer. *Tuberkuloz ve toraks*, *53*(2), 200–209.
- Park, B., Kim, Y., Lee, J., Lee, N., & Jang, S. H. (2020). Sex difference and smoking effect of lung cancer incidence in Asian population. *Cancers*, *13*(1), 113. <https://doi.org/10.3390/cancers13010113>.
- Patel, A. V., Friedenreich, C. M., Moore, S. C., Hayes, S. C., Silver, J. K., Campbell, K. L., Winters-Stone, K., Gerber, L. H., George, S. M., Fulton, J. E., Denlinger, C., Morris, G. S., Hue, T., Schmitz, K. H., & Matthews, C. E. (2019). American College of Sports Medicine Roundtable report on physical activity, sedentary behavior, and cancer prevention and control. *Medicine and science in sports and exercise*, *51*(11), 2391–2402. <https://doi.org/10.1249/MSS.0000000000002117>.
- Patel, A. V., Carter, B. D., Stevens, V. L., Gaudet, M. M., Campbell, P. T., & Gapstur, S. M. (2017). The relationship between physical activity, obesity, and lung cancer risk by smoking status in a large prospective cohort of US adults. *Cancer Causes & Control*, *28*(12), 1357–1368. <https://doi.org/10.1007/s10552-017-0949-0>.
- Polak, M., Genowska, A., Szafraniec, K., Fryc, J., Jamiołkowski, J., & Pająk, A. (2019). Area-based socio-economic inequalities in mortality from lung cancer and respiratory diseases. *International Journal of Environmental Research and Public Health*, *16*(10), 1791. <https://doi.org/10.3390/ijerph16101791>.
- Proctor, R. N. (2012). The history of the discovery of the cigarette – lung cancer link: Evidentiary traditions, corporate denial, global toll: Table 1. *Tobacco Control*, *21*(2), 87–91. <https://doi.org/10.1136/tobaccocontrol-2011-050338>.
- R Core Team. (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing. <https://www.R-project.org/>.
- Raaschou-Nielsen, O., Andersen, Z. J., Beelen, R., Samoli, E., Stafoggia, M., Weinmayr, G., Hoffmann, B., Fischer, P., Nieuwenhuijsen, M. J., Brunekreef, B., Xun, W. W., Katsouyanni, K., Dimakopoulou, K., Sommar, J., Forsberg, B., Modig, L., Oudin, A., Oftedal, B., Schwarze, P. E., ... Hoek, G. (2013). Air pollution and lung cancer incidence in 17 European cohorts: Prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). *The Lancet Oncology*, *14*(9), 813–822. [https://doi.org/10.1016/s1470-2045\(13\)70279-1](https://doi.org/10.1016/s1470-2045(13)70279-1).
- Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F. (2021). Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer Journal for Clinicians*, *71*(3), 209–249. <https://doi.org/10.3322/caac.21660>.
- The UNESCO Institute for Statistics (UIS). (2020, August 26). [dataset] *Education: mean years of schooling*. <http://data.uis.unesco.org/Index.aspx?queryid=242>.

- Turner, M. C., Andersen, Z. J., Baccarelli, A., Diver, W. R., Gapstur, S. M., Pope, C. A., III, Prada, D., Samet, J., Thurston, G., & Cohen, A. (2020). Outdoor air pollution and cancer: An overview of the current evidence and public health recommendations. *CA: A Cancer Journal for Clinicians*, 70(6), 460–479. <https://doi.org/10.3322/caac.21632>.
- Wang, A., Qin, F., Hedlin, H., Desai, M., Chlebowski, R., Gomez, S., Eaton, C. B., Johnson, K. C., Qi, L., Wactawski-Wende, J., Womack, C., Wakelee, H. A., & Stefanick, M. L. (2016). Physical activity and sedentary behavior in relation to lung cancer incidence and mortality in older women: The Women's Health Initiative. *International Journal of Cancer*, 139(10), 2178–2192. <https://doi.org/10.1002/ijc.30281>.
- Wild, C. P., Weiderpass, E. & Stewart, B. W. (Eds.) (2020). World cancer report: Cancer research for cancer prevention. Lyon, France: International Agency for Research on Cancer. <http://publications.iarc.fr/586>.
- Williams, D. R., Kontos, E. Z., Viswanath, K., Haas, J. S., Lathan, C. S., MacConaill, L. E., Chen, J., & Ayanian, J. Z. (2012). Integrating multiple social statuses in health disparities research: The case of lung cancer. *Health Services Research*, 47(3pt2), 1255–1277. <https://doi.org/10.1111/j.1475-6773.2012.01404.x>.
- World Health Organization. (2020a). [dataset] *Domestic general government health expenditure (GGHE-D) as percentage of gross domestic product (GDP) (%) – Data by country*. WHO; World Health Organization. <https://apps.who.int/gho/data/node.main.GHEDGGHEDGDPSHA2011?lang=en>.
- World Health Organization. (2020b). Global health estimates 2020: Deaths by cause, age, sex, by country and by region, 2000–2019. <https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/ghe-leading-causes-of-death>, World Health Organization, accessed on August, 14, 2021.
- Zhong, S., Ma, T., Chen, L., Chen, W., Lv, M., Zhang, X., & Zhao, J. (2016). Physical activity and risk of lung cancer. *Clinical Journal of Sport Medicine*, 26(3), 173–181. <https://doi.org/10.1097/jsm.000000000000219>.

## Annex

TABLE 2.A1 Cluster analysis data by country

Country	Cluster	Lung mortality (per 100,000)	GDP/capita (EUR)	HC spending (%)	Years of education	PM10 days	Alcohol (liters)	Smoke (%)	Diet (%)	Obese (%)	Sports club (%)	Sports activity (%)
ES	1	49.87	23,220.00	6.50	9.97	10.22	8.26	19.00	8.00	16.20	0.07	0.46
IT	1	59.07	27,260.00	6.70	10.19	33.27	7.14	11.00	6.00	10.50	0.07	0.30
MT	1	40.88	21,620.00	5.60	11.25	18.50	7.75	13.00	16.00	25.20	0.06	0.19
PT	1	40.65	17,350.00	5.90	9.11	9.87	10.54	6.00	18.00	16.10	0.04	0.28
RO	1	52.43	8,090.00	3.90	10.91	14.53	10.40	20.00	1.00	9.10	0.01	0.21
BG	2	52.20	6,360.00	4.20	11.28	63.63	11.30	31.00	24.00	14.40	0.02	0.11
CY	2	47.85	21,030.00	2.90	11.95	37.00	9.55	23.00	15.00	13.90	0.06	0.36
EL	2	70.54	16,380.00	4.60	10.75	40.67	10.56	29.00	29.00	16.90	0.05	0.31
HR	2	69.47	10,600.00	5.60	12.05	34.55	9.89	25.00	26.00	18.00	0.10	0.35
HU	2	93.29	11,400.00	4.70	11.91	28.52	10.90	22.00	3.00	20.60	0.05	0.38
PL	2	71.38	11,190.00	4.40	13.09	55.30	10.48	21.00	3.00	16.70	0.03	0.28
AT	3	48.81	39,890.00	7.50	12.18	7.88	11.40	24.00	27.00	14.30	0.13	0.45
BE	3	66.13	36,960.00	8.00	12.01	11.35	10.36	12.00	9.00	13.70	0.16	0.47

TABLE 2.A1 Cluster analysis data by country (cont.)

Country	Cluster	Lung mortality (per 100,000)	GDP/capita (EUR)	HC spending (%)	Years of education	PM10 days	Alcohol (liters)	Smoke (%)	Diet (%)	Obese (%)	Sports club (%)	Sports activity (%)
DE	3	61.24	37,090.00	8.50	14.15	8.76	11.99	9.00	2.00	16.40	0.24	0.48
DK	3	70.26	48,050.00	8.60	12.61	10.71	9.38	8.00	20.00	14.40	0.25	0.68
FI	3	41.99	38,570.00	7.50	12.71	8.07	8.51	4.00	10.00	17.80	0.12	0.66
FR	3	56.08	33,020.00	8.80	11.40	5.40	11.87	25.00	13.00	14.70	0.16	0.43
IE	3	41.86	55,970.00	5.30	11.40	3.25	10.93	10.00	21.00	18.20	0.19	0.52
LU	3	48.55	91,440.00	4.60	13.60	4.75	11.83	5.00	14.00	15.10	0.21	0.54
NL	3	69.39	40,730.00	6.70	12.23	9.06	8.03	16.00	19.00	12.90	0.27	0.58
SE	3	40.47	46,350.00	9.20	12.43	9.12	7.16	1.00	30.00	13.40	0.22	0.70
CZ	4	54.13	15,980.00	6.00	12.81	24.10	12.82	25.00	31.00	18.70	0.11	0.36
EE	4	51.13	15,820.00	4.80	13.90	4.43	16.64	26.00	17.00	19.70	0.12	0.39
LT	4	47.31	12,850.00	4.30	13.08	18.87	14.42	18.00	11.00	16.60	0.08	0.37
LV	4	48.53	12,350.00	3.40	12.98	15.17	10.82	28.00	5.00	20.80	0.06	0.31
SI	4	55.53	18,830.00	6.10	12.66	33.07	11.49	14.00	28.00	18.60	0.12	0.51
SK	4	44.00	14,710.00	5.40	12.78	22.22	10.78	27.00	4.00	15.90	0.07	0.34

SOURCE: AUTHORS' ELABORATION

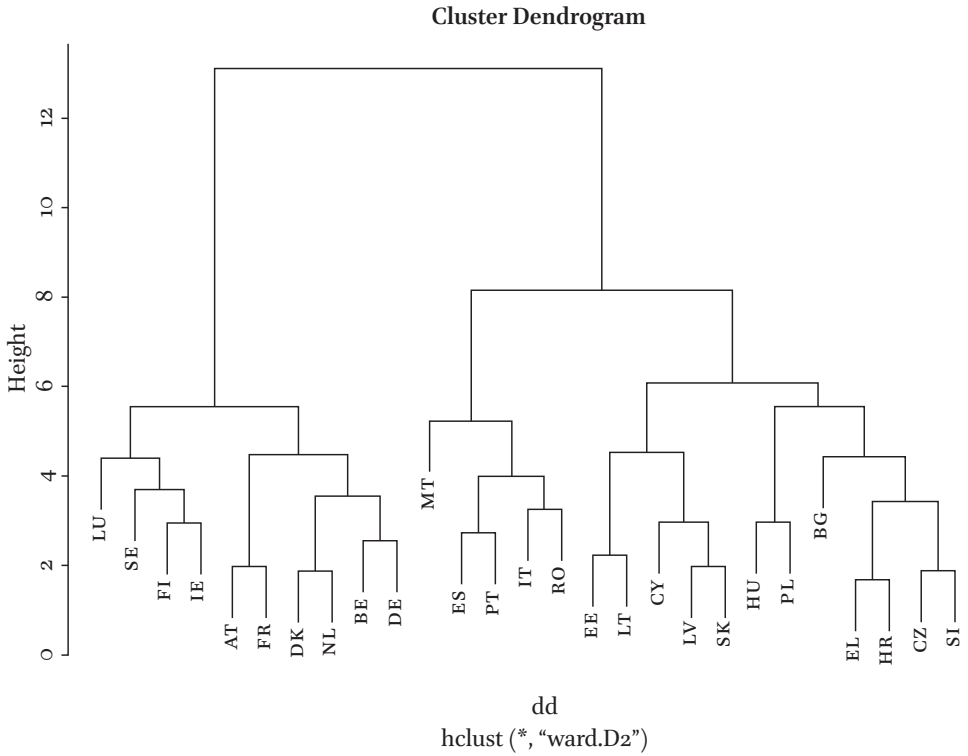


FIGURE 2.A Cluster dendrogram based on hierarchical clustering  
SOURCE: AUTHORS' ELABORATION

TABLE 2.A2 Multiple linear regression results for normalized lung cancer mortality

Variable	Estimate	Std. error	t value	Pr(> t )
GDP percapita	-0.216	0.336	-0.644	0.5288
HC expenditure	0.012	0.285	0.042	0.9672
years of edu	-0.588	0.321	-1.832	0.0856 <sup>a</sup>
diet	-0.605	0.228	-2.655	0.0173 <sup>b</sup>
smoke currently	0.368	0.279	1.322	0.2047
Liter consumption	0.285	0.268	1.062	0.3039
Obese	0.223	0.206	1.082	0.2955
PM10 days	0.914	0.297	3.082	0.0072 <sup>c</sup>
sports.activity	0.528	0.372	1.417	0.1757
sports.club	0.955	0.460	2.075	0.0545 <sup>b</sup>

Note: Significance: p<0.1 (a) p<0.05 (b) p<0.01 (c)

SOURCE: AUTHORS' ELABORATION

# Trends in Incidence of Zoonotic Foodborne Diseases in the United States in 2010–2019

*Sayansk Da Silva and Joseph E. Hibdon, Jr.*

## Abstract

Zoonotic foodborne diseases are infections of the gastrointestinal tract that occur as a result of the ingestion of food containing pathogens that are transmitted between non-human animals and people. With the growing concern about food safety and zoonotic diseases, it is imperative to keep these illnesses under surveillance in order to develop an efficient program for control and prevention. In this work, we examine trends in the occurrence of nationally notifiable zoonotic foodborne diseases during 2010–2019 by using data retrieved from databases from the Centers for Disease Control and Prevention. We focused on some of the foodborne diseases that are particularly relevant to public health authorities: salmonellosis, Shiga toxin-producing *Escherichia coli* (STEC) infection, campylobacteriosis, listeriosis, and vibriosis. We analyzed the relationship between the number of cases of these diseases and the per capita consumption of animal products. Additionally, the US data on foodborne diseases were compared to the data from other countries. The results show that from 2010 to 2019 the incidence of vibriosis more than tripled and the incidence of STEC infection more than doubled. Listeriosis accounted for the lowest incident rates, ranging from 0.23 to 0.28. There is a positive association between the consumption of animal products and foodborne diseases such as STEC infection. The data shows that the incidence of these diseases is increasing and indicates that greater public health efforts are necessary to control these illnesses.

## Keywords

food safety – zoonotic diseases – United States

## 1 Introduction

Foodborne diseases (FBDs) can be described as pathological alterations that arise as a result of the ingestion of contaminated food. This contamination may be associated with a variety of causes including harmful microorganisms, toxins, and substances that can cause harm to the human body. The most common signs and symptoms of these diseases are associated with the gastrointestinal tract; including nausea, diarrhea, and vomiting as manifestations most frequently reported. Besides the gastrointestinal symptoms that are commonly seen, foodborne pathogens can also affect other parts of the body such as cardiovascular, respiratory, and musculoskeletal systems (Kuchenmüller, 2013). Although global food safety awareness has increased over the decades, FBDs constitute an economic and public health issue in many countries around the world. Their impact is particularly concerning in low- and middle-income countries where strategies for disease surveillance are not well established. International organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) have determined methods to analyze and keep track of specific FBDs.

The WHO (2015) estimated that about 600 million cases of illnesses caused by foodborne hazards occurred globally in 2010. Over 90% of these cases were caused by infectious agents that provoke diarrhea, and zoonotic pathogens represented the main microorganisms involved in this public health issue (WHO, 2015). The Joint WHO/FAO Expert Committee in Zoonoses (1959) described zoonoses as infections and diseases that are naturally transmitted between animals and people. The transmission of these infectious diseases is intimately related to the domestication of animals, which brings together humans and several other species of vertebrates. This close contact may have changed the dynamics of animal-human interactions in a way that facilitated the transmission of diseases from domestic animals to people. Although the domestication process had different purposes, animals farmed for food include important reservoirs for multiple foodborne microorganisms.

## 2 Zoonotic Foodborne Diseases

Zoonotic foodborne pathogens include a variety of infectious agents such as bacteria (e.g. *Campylobacter jejuni*), viruses (e.g. norovirus), and parasites (e.g. *Taenia solium*). However, the most common zoonotic FBDs have their etiology attributed to bacterial pathogens (European Food Safety Authority,



n.d.). Moreover, these microorganisms are the leading cause when it comes to diseases transmitted through food, being responsible for more than 65% of the reported outbreaks of FBDS (Le Loir et al., 2003). Of every 10 diseases in humans, six are considered zoonotic (Phillips, 2021) with many of them being transmitted through food and water. The importance of zoonotic FBDS has been recognized at local, national, and global levels. In the United States (US), for example, salmonellosis occupies the second position in the list of top zoonotic diseases of national concern (Animal and Plant Health Inspection Service, 2020; Centers for Disease Control and Prevention [CDC], 2020).

### 2.1 *Zoonotic Foodborne Parasites*

Protozoan and helminth species of internal parasites are the organisms involved in parasitic foodborne infection in people (Murrel, 2013). Although there are divergences in terms of classifications, the Protozoa are considered to be a subkingdom of the Protista kingdom and include a variety of unicellular eukaryotic organisms (Yaeger, 1996). They are mainly microscopic organisms, and most parasitic protozoa in people have a size less than 50 micrometers (Singleton, 2018). On the other hand, helminths are multicellular organisms that are classified into two phyla: Nematelminthes (roundworms) and Platyhelminthes (flatworms) (Mahamud et al., 2018). Nematelminthes include approximately 500,000 species, and they can cause disease to plants, animals, and humans (John & Petri, 2020). Platyhelminthes are one of the largest animal phyla and include over 20,000 species (Adell et al., 2015). The diseases caused by some parasites are classified as neglected tropical diseases, which are a group of diseases that primarily affect poor populations living in tropical and subtropical climates (WHO, 2012). This group of diseases include important zoonotic foodborne parasites such as species from the *Echinococcus* and *Taenia* genera.

### 2.2 *Bacterial Zoonotic Foodborne Pathogens*

Bacteria are prokaryotic microorganisms that have different morphologic characteristics, which are analyzed as part of their identification process. Bacteria cells have different shapes with the most common being rods, spheres, and spirals. Although their cell structure may appear simple when compared to eukaryotic cells, bacteria have a complex set of components that can determine how dangerous they are to humans. The cell wall of these microorganisms is organized in two basic forms that are defined based on the results of the Gram staining technique. Gram-positive bacteria have a cell wall with a thick layer of peptidoglycan whereas those that are Gram-negative have a thin layer of peptidoglycan and an outer membrane that is not found in Gram-positive cells.

Additionally, bacteria may carry extracellular components such as fimbriae, flagella, and capsules, which offer structural support and facilitate the agent-host interaction through bacterial colonization, mobility, and exchange of genetic materials (Bhunja, 2018a). Some surface structures are important virulence factors that give bacteria the ability to infect the host, cause disease, and bypass the immune system defenses. The pathogenicity of bacteria that cause FBDS rely on their capacity to penetrate, survive, and multiply in hosts cells along with their ability to produce toxins (Le Loir et al., 2003). Besides pathogens' virulence factors, the host characteristics including age and immune status are also factors that need to be considered in the dynamics of FBDS.

The most common species of bacteria involved in FBDS include *Salmonella enterica*, *Escherichia coli*, and *Campylobacter jejuni* (Bintsis, 2017; WHO, 2020a; Zhao et al., 2014). Other pathogens with relevance to public health are species from the *Vibrio* genus and *Listeria monocytogenes*. All these microorganisms

TABLE 3.1 Summary of important zoonotic foodborne bacteria

Pathogen	Characteristics	Example of animal reservoir	Typical incubation period
<i>Salmonella</i> Typhimurium	Gram-negative, rod-shaped, aerobic to facultative anaerobic, non-spore-forming	Poultry, pigs, and cattle	12–72 hours
Shiga toxin-producing <i>Escherichia coli</i>	Gram-negative, rod-shaped, facultative anaerobic, non-spore-forming	Cattle, goats, sheeps, and deer	3–4 days
<i>Campylobacter jejuni</i>	Gram-negative, helix-shaped, microaerobic, non-spore-forming	Poultry, cattle, and wild birds	2–5 days
<i>Listeria monocytogenes</i>	Gram-positive, rod-shaped, facultative anaerobic, non-spore-forming	Cattle, goats, and sheeps	1–2 weeks
<i>Vibrio parahaemolyticus</i>	Gram-negative, rod-shaped, facultative anaerobic, non-spore-forming	Shellfish and fish	4–96 hours

SOURCE: AUTHORS' ELABORATION

are considered important causative agents of zoonotic FBDS, and they are also responsible for economic and production losses in animal farming. Additionally, even though these pathogens can infect humans through the ingestion of contaminated food, people may become infected through different routes including direct interaction with infected animals. Moreover, food may become contaminated due to cross-contamination where bacteria on surfaces, for example, may be transferred to food during the preparation process. *S. enterica* serovar Enteritidis and *Campylobacter jejuni* have been noted to continue to be viable on dry stainless-steel surfaces at room temperature and represent a possible cross-contamination risk (Stein & Chirilă, 2017).

### 2.2.1 *Salmonella* spp.

Salmonellae are Gram-negative, rod-shaped bacilli that are taxonomically divided into two species: *S. enterica* and *S. bongori* (CDC, 2019a). The former is classified into six subspecies that can be distinguished from each other with the use of biochemical tests: *S. enterica* subsp. *enterica*, *S. enterica* subsp. *salamae*, *S. enterica* subsp. *arizonae*, *S. enterica* subsp. *diarizonae*, *S. enterica* subsp. *houtenae* and *S. enterica* subsp. *Indica* (Grimont & Weill, 2007). Additionally, *Salmonella* is a facultative intracellular microorganism that can colonize the intestinal tract of a variety of homoeothermic and poikilothermic animals (Liu, 2018). More than 2,500 serovars of *Salmonella* have been reported worldwide and categorized based on somatic (O) and flagellar (H) antigens (Agbaje et al., 2011). The majority of the isolates that cause disease in mammals including humans belong to *S. enterica* subsp. *enterica*, and the nontyphoidal *Salmonella* serovars represent the group that are zoonotic or potentially zoonotic (The Center for Food Security & Public Health, 2013).

Common sources of contaminated food include eggs, poultry, and beef, and infection occurs in the summer months with higher frequency (CDC, 2019a). Usually, an infectious dose greater than 50,000 bacterial cells is necessary to set off a disease in humans, and the onset of symptoms occur between 6 to 72 hours after the consumption of contaminated food (Coburn et al., 2007). The clinical manifestations of FBDS are generally associated with alterations in the gastrointestinal system. However, individuals in high-risk groups such as those that are immunocompromised and the elderly may develop bacteremia as a complication of an infection caused by nontyphoidal *Salmonella* (Acheson & Hohmann, 2001).

The diagnostic of salmonellosis can be done through laboratory tests that detect bacterial cells or genetic material in stools, body tissue, or fluids of people who have been infected (CDC, 2019b). The traditional *Salmonella* culture method include pre-enrichment, selective enrichment, isolation of pure

culture, biochemical tests, and serological confirmation (Bhunia, 2018b). Other methods used to identify and categorize salmonellae are polymerase chain reaction (PCR) and real-time PCR assays that work by targeting a variety of *Salmonella* genes including *16S rRNA*, *agfA*, and *viaB* (Gwida & Al-Ashmawy, 2014). Preventive and control measures include rigorous strategies throughout the food chain in order to avoid food contamination. Furthermore, basic hygiene practices and avoiding the consumption of raw animal products are examples of preventive measures that can be adopted by the general population.

### 2.2.2 Escherichia coli

The *Escherichia* genus is currently divided into five species: *E. albetii*, *E. coli*, *E. fergusonii*, *E. hermannii*, and *E. vulneris* (Schmidt, 2019). The species *E. coli* is one of the most studied in this genus, particularly in research that investigates its role in cases of FBDS. *E. coli* is a Gram-negative, facultative anaerobic bacillus that can be either motile or nonmotile (Desmarchelier & Fegan, 2011). This bacillus can be found in the gastrointestinal tract of a variety of species including humans, cattle, goats, and pigs. Even though most strains of *E. coli* are harmless, some strains are involved in cases of severe illnesses in people (WHO, 2018a). The strains of this species are serologically differentiated by O, H, and capsular (K) antigens (Nataro & Kaper, 1998). Over 700 serotypes have been identified so far, and as to serotyping strains of *E. coli* associated with diarrheal disease, it is necessary to determine only the O and H antigens (Doyle et al., 2020).

The term diarrheagenic *E. coli* is commonly used to classify the strains of this species responsible for causing gastrointestinal infections. The groups of strains of diarrheagenic *E. coli* can be differentiated based on their virulence factors and pathogenesis, and they include enteropathogenic *E. coli* (EPEC), Shiga toxin-producing *E. coli* (STEC), enteroinvasive *E. coli* (EIEC), enteroaggregative *E. coli* (EAEC), enterotoxigenic *E. coli* (ETEC), diffusely-adherent *E. coli* (DAEC), and adherent-invasive *E. coli* (AIEC) (Croxen et al., 2013; Nataro & Kaper, 1998). The STEC pathotype is also known as Verocytotoxin-producing *E. coli* (VTEC) or enterohemorrhagic *E. coli* (EHEC), and it is the group most commonly linked to foodborne outbreaks (CDC, 2014). As suggested by its name, the nomenclature of this group refers to an *E. coli* strain that acquired the capacity to produce Shiga toxin (Stx) through the transfer of one or both genes (i.e. *stx1a* and *stx2a*) by a Stx phage (Byrne et al., 2015; Petro et al., 2019; Travert et al., 2021). STEC is naturally found in the microbiota of ruminants, which are the most important reservoirs of this zoonotic pathogen (Ballem et al., 2020). Additionally, *E. coli* O157:H7 is the most important and frequently

isolated serotype of STEC (Siddiqui & Yuan, 2021; Tian et al., 2018). Moreover, the low infectious dose of *E. coli* O157:H7 may be one of the factors why this serotype is involved in many outbreaks. As few as 10 viable bacterial cells have the potential to cause disease in humans (Ameer et al., 2021; Etcheverria & Padola, 2013).

The clinical manifestations of STEC infection comprise of severe stomach cramps, diarrhea, vomiting, and, in some cases, fever (CDC, 2014). Between 5 and 15% of the patients that have symptomatic STEC infection develop a severe condition known as hemolytic uremic syndrome (HUS), which may lead to kidney failure (Bruyand et al., 2018). In terms of diagnosis, O157 STEC can be differentiated from most natural *E. coli* that inhabit the intestines by their inability to ferment sorbitol within 24 hours on a selective medium such as sorbitol-MacConkey agar (Gould & STEC Clinical Laboratory Diagnostics Working Group, 2012). Additionally, PCR can be used as a molecular method for STEC identification, and it has good sensitivity and specificity for the detection in different sources of infection (Castro et al., 2017).

### 2.2.3 *Campylobacter spp.*

Over 20 species have been assigned to the *Campylobacter* genus, but *C. jejuni* and *C. coli* are the most commonly isolated from humans (Man, 2011). *Campylobacter* spp. are Gram-negative, non-spore-forming bacteria that are usually motile by means of a single polar unsheathed flagellum at one or both ends of the cell (Silva et al., 2011). Species from the *Campylobacter* genus have a helical shape, but they have the ability to change their structure and become rod- or coccoid-shaped (Esson et al., 2016). *Campylobacter* spp. are commensal microorganisms of the gastrointestinal tract of many farm, wild, and companion animals, which are reservoirs for human infection (Facciola et al., 2017; Fitzgerald & Nachamkin, 2015). Among the zoonotic species of this genus, *C. jejuni* is responsible for over 81% of the cases of campylobacteriosis in people (Liu, 2018).

The incubation period (i.e. time between becoming infected and presenting symptoms) of campylobacteriosis is typically two to five days, but it can range from 1 to 10 days (WHO, 2020b). Infectious doses between  $8 \times 10^2$  to  $2 \times 10^9$  cells of *C. jejuni* have been shown to cause diarrheal diseases in humans (Black et al., 1988). As for most bacterial FBDS, the clinical manifestations of campylobacteriosis include diarrhea, intense abdominal pain, nausea, and vomiting. About 0.1% of individuals infected with campylobacteriosis develop Guillain-Barré syndrome, which is a serious autoimmune disorder that can cause muscle weakness and paralysis (Janssen et al., 2008; CDC, 2019c). Since

there are no specific symptoms that can help to confirm a case of campylobacteriosis, different diagnostic methods have been used such as PCR, DNA microarray, enzyme-linked immunosorbent assay (ELISA), biochemical characterization, and serotyping (Choudhary et al., 2021).

#### 2.2.4 *Listeria monocytogenes*

*Listeria* spp. are Gram-positive, rod-shaped, non-spore-forming, facultative aerobic bacteria that are motile by means of a few peritrichous flagella (Wang & Orsi, 2013). *Listeria* spp. includes 20 recognized species, and *L. monocytogenes* represents the most pathogenic member of the genus (Nwaiwu, 2020). Based on O and H antigens, 13 serotypes of *L. monocytogenes* have been identified, and the serotypes 1/2a, 1/2b, 1/2c, and 4b are the most commonly found in food and the food production environment (Jamshidi & Zeinali, 2019). Cattle and small ruminants including goats and sheep are important reservoirs of *L. monocytogenes* and their feces can carry this pathogen and, consequently, contaminate the soil and surrounding environment (Vivant et al., 2013). Moreover, the infective dose of *L. monocytogenes* has been estimated to be 10 to 100 million CFU in healthy individuals, and 0.1 to 10 million CFU in people at high risk (Government of Canada, 2012). Examples of individuals at high risk are those who are immunocompromised, pregnant, or over 65 years.

In humans, listeriosis can occur in two forms: noninvasive listeriosis and invasive listeriosis. The former is a mild manifestation of the disease and has symptoms that include diarrhea, headache, and fever, whereas the latter is a severe form of the disease that particularly affects people at high risk and has symptoms such as fever, myalgia, septicemia, and meningitis (WHO, 2018b). It is important to mention that this disease has high mortality rates, ranging from 20 to 30% (Hernandez-Milian & Payeras-Cifre, 2014). The diagnosis of this disease is made through cultures of blood, spinal fluid, or other body cavity fluids (Mcneil et al., 2017). Furthermore, the diagnosis of listeriosis during pregnancy is difficult as about 30% of the cases are asymptomatic; however, if disease is suspected, placental cultures are considered the gold standard for diagnosis of maternal fetal listeriosis (Serventi et al., 2020).

#### 2.2.5 *Vibrio* spp.

The *Vibrio* genus has over 70 species that are ubiquitous and abundant in aquatic environments (Kokashvili et al., 2015). The components of this genus are Gram-negative, facultative anaerobic, rod-shaped bacteria with a single polar flagellum, and, with the exception of *V. cholerae* and *V. mimicus*, all species are halophilic (Long et al., 2017). *Vibrio* spp. represent the cause of most

human diseases associated with microorganisms of aquatic environments and seafood, and *V. cholerae*, *V. parahaemolyticus*, *V. alginolyticus*, and *V. vulnificus* the most common pathogenic species (Baker-Austin et al., 2018). In the United States, environmental factors such as temperature and salinity of water have been determined to be predictors of *V. parahaemolyticus* and *V. vulnificus* abundance (Raszl et al., 2016).

Individuals infected with *Vibrio* spp. may be asymptomatic or may present clinical manifestations such as diarrhea, abdominal pain, nausea, vomiting, fever, headache, and myalgia (Baker-Austin et al., 2018; Liu, 2018). In terms of microbiological diagnosis, the thiosulfate citrate bile-salts sucrose (TCBS) agar is the standard medium used for selective isolation of *Vibrio* species. Furthermore, culture independent methods such as PCR can be used to quantify *Vibrio* spp. in different sources of infection (Givens et al., 2014).

### 3 Food Chain and Food Contamination

Analyzing the food supply chain in terms of animal production is an essential part of understanding the dynamics of zoonotic FBDs. Several pathogens have been linked to agricultural and food preparation practices, which is one of the reasons why food safety measures are constantly being developed and put in place. Analyses have shown that agricultural drivers were associated with approximately 50% of zoonotic diseases that emerged in human since 1940 (Rohr et al., 2019). Moreover, population growth and demographic changes are expected for the next decades along with an amplification of the already intensive animal farming system (Godfray & Garnett, 2014). If no plan of effective control measures is adopted, the intensification of the food supply chain will allow the spread of pathogens in a much larger scale than the one currently seen. Because the incidence of infectious diseases typically increases proportionally with the increase of host density, the rise in human and livestock densities could also affect the spread of pathogens (Jones et al., 2013; Rohr et al., 2019). In addition, new zoonotic foodborne pathogens may appear during this process, and the development and implementation of surveillance systems is an essential step to control them.

Food contamination occurs when microorganisms or chemicals get into food products and their presence make the food unsafe. The contamination of food products may occur during different stages of the food chain such as production, processing, distribution, preparation, and the final consumption (Abebe et al., 2020). A variety of animal products are subjected to contamination, the most common being eggs, meat, poultry, and dairy products. One



comprehensive approach to address issues related to food contamination is the adoption of strategies based on Hazard Analysis Critical Control Point (HACCP). This is a management system that addresses food safety through the identification, evaluation, and control of hazards (US Food and Drug Administration, 2018).

#### 4 Global Burden of Foodborne Diseases

Foodborne diseases are a public health concern worldwide, but they affect countries at different levels. Low- and middle-income nations are the most impacted by these diseases and also the countries with the lowest performances with regards to disease surveillance. Although food safety and FBD awareness have increased globally, strategies to efficiently monitor and control the spread of foodborne pathogens still lack in those countries. Even though FBDS have been causing economic losses and public health concerns for a long time, only a few countries have assessed the burden of these infectious diseases. Moreover, not every person who becomes ill after ingestion of contaminated food seeks the healthcare system, which contributes to the gap that exists between the reported data and the real scenario. Even though this chapter does not enter into the merit of issues related to healthcare access, it is important to mention that lack of access to quality healthcare is a contributing factor for the underreport of FBDS. The lack of surveillance and data on FBDS also prevents health authorities from analyzing past trends, which could help to develop new approaches for limiting the burden.

The first estimates on global and regional burden of FBDS was presented only in 2015 and was led by the WHO. The report provides readers with estimates of incidence and mortality rates along with disease burden in terms of Disability Adjusted Life Years (DALYS) caused by 31 foodborne hazards. DALYS for a disease or condition are the total sum of the years of life lost due to premature mortality and the years lived with a disability (WHO, n.d.). Although norovirus was responsible for the most DALYS worldwide in 2010 (i.e. over 15 million DALYS), bacterial pathogens such as *S. enterica* and *E. coli* represented important causes of DALYS (WHO, 2015). Furthermore, human-to-human contact was the main route of transmission of norovirus for most regions, whereas food represented the principal route of transmission for Shiga toxin-producing *E. coli*, Non-typhoidal *S. enterica*, and *Campylobacter* spp. in all regions. This fact highlights the importance of research at all levels on the interplay between humans, zoonotic pathogens and their animal reservoirs, and animal food products.



## 5 The United States Context

Foodborne illnesses have an impact on countries' health and economic systems worldwide. In the United States, it was estimated that foodborne pathogens caused an economic burden of \$17.6 billion, which is 13% higher than the 2013 estimate (Economic Research Service, 2021). Other estimates show that the annual economic burden of FBDS in Australia and New Zealand is respectively \$1.289 billion and \$86 million (McLinden et al., 2014). National public health estimates on this issue show that 48 million people get sick and 3,000 die of FBDS every year (CDC, 2018). These estimates highlight the impact of FBDS in the country and the value of epidemiological analyses that keep these diseases under surveillance.

One of the tools used to monitor FBDS in the US is the National Notifiable Disease Surveillance System (NNDSS). The NNDSS is an integrated system that allows public health at all levels (i.e. local, national, and global) to share data that is used to monitor, control, and prevent the occurrence and spread of notifiable diseases and conditions (US Department of Health and Human Services, n.d.). The list of nationally notifiable infectious diseases includes zoonotic FBDS such as salmonellosis, campylobacteriosis, STEC infection, listeriosis, and vibriosis. These are diseases for which more data is necessary to develop effective control and preventive measures in order to reduce their occurrence and spread. Additionally, the Healthy People initiative set health-related national objectives on a 10-year basis for improving the health and well-being of all individuals. These objectives can be used as comparison measurements to assess the progress towards the control of infectious diseases.

## 6 Analysis of Trends in Zoonotic Foodborne Diseases

The trends on the incidence of many zoonotic FBDS have varied throughout the years. The US list of Nationally Notifiable Infectious Diseases and Conditions is comprised of many illnesses caused by different pathogens. Some of the zoonotic FBDS include salmonellosis, STEC infection, listeriosis, campylobacteriosis, and vibriosis. Epidemiologic data on these diseases can be retrieved from the NNDSS for the US and from the European Centre for Disease Prevention and Control for countries of the European Union. Additionally, the Public Health Agency of Canada also provides epidemiological data regarding these diseases. It has to be noted that despite the fact these diseases are commonly transmitted through contaminated food, the proportion of cases

TABLE 3.2 Reported cases of zoonotic foodborne diseases in the United States, 2010–2019

Year	Reported number of cases			
	Salmonellosis	STEC infection	Listeriosis	Campylobacteriosis
2010	54,424	5,476	821	na
2011	51,887	6,047	870	na
2012	53,800	6,463	727	na
2013	50,634	6,663	735	na
2014	51,455	6,179	769	na
2015	55,108	7,059	768	54,556
2016	53,850	8,169	786	60,120
2017	54,285	8,672	887	67,537
2018	60,999	15,996	864	70,200
2019	54,578	16,939	880	71,509
$\bar{x}$ (sd)	54,102 (2,848.761)	8,766.3 (4,176.468)	810.7 (61.4601)	64,784.4 (7,219.809)

SOURCE: AUTHORS' ELABORATION

linked to food consumption is not available. Also, each disease has a case definition that includes clinical and laboratory criteria as part of its diagnosis in the United States.

From 2010 to 2019, some changes were seen in the incidence rate (IR) of major zoonotic FBDS. Fluctuations were observed in the incidence of salmonellosis with rates varying from 17.59 cases per 100,000 people in 2010 to 16.63 cases per 100,000 people in 2019. Unless specified otherwise, for the remainder of this chapter, IR represents the number of cases per 100,000 people. During those 10 years, the highest rate was reported in 2018 with an incidence of 18.67. The Healthy People initiative had targeted for 2020 an incidence of salmonellosis of 11.4 (Office of Disease prevention and Health Promotion [ODPHP], 2021). This substantial decrease in new cases of salmonellosis is an ambitious aim that continues in place as an objective of the Healthy People 2030. The persistence of this disease has also been observed in other countries. The Canadian government has reported IRs of salmonellosis varying from 17.63 in 2013 to 19.24 in 2018 with a peak in 2014, when the country registered 21.56 cases of this disease per 100,000 people.

The US incidence of STEC infection has been continuously rising since 2014 when the country reported a total of 6,179 cases. An increase greater than two-fold in the number of cases was registered in 2019, accounting for an IR of 5.16. The US national objective for 2020, however, was to reduce the incidence of STEC infections to 0.6 cases per 100,000 people (ODPHP, 2021). A similar trend has been observed in European countries such as Denmark and Norway. Even though these countries have a much lower number of cases when compared to the US, the incidence of STEC infection there is increasing at a high rate. On the other hand, the Netherlands have been progressively reducing the occurrence of this disease, reporting 459 cases in 2019. Although many factors play a role in the dynamics of this infection, it was found that there is a relationship between the number of cases of STEC infection in the US and the per capita consumption of chicken in the country.

Between 2010 and 2019, the US has reported low IRs of listeriosis, ranging from 0.23 to 0.28. The highest number of cases in this period of time was observed in 2017 when the country reported a total of 887 cases, which represented an IR of 0.27. In the same year, Germany and France had the highest number of cases of listeriosis in the European Union, registering a total of 726 and 370 confirmed cases, respectively. Because of the difference in population size between these two European countries and the US, they reported a much higher IR of listeriosis for that year (i.e. Germany: 0.88 cases per 100,000 people and France: 0.55 cases per 100,000 people). An incidence higher than that of the US was also found in Canada where a rate of 0.33 was reported. The Healthy People 2020 target for this disease was a rate of 0.2 cases per 100,000 people (ODPHP, 2021). Although there is some small fluctuation in the incidence of listeriosis throughout the last decade, this disease seems to be under control. However, its high mortality rate makes it a disease that needs to be constantly under surveillance.

Campylobacteriosis became a nationally notifiable disease in the US in 2015. Annual national data on this disease has been released since then. The number of cases of this disease have been annually increasing since its first report in 2015. In 2019, the country reported 71,509 cases of campylobacteriosis, making it the nationally notifiable FBD with the highest number of cases in that year. In 2017, the US had an IR of 20.78, which was lower than that reported by most European countries in the same year. From 2015 to 2019, the IR of campylobacteriosis increased from 17.01 to 21.79. The national goal, however, was to decrease it to 8.5 cases per 100,00 by 2020 (ODPHP, 2021). Additionally, the number of cases of vibriosis has also increased over the years in the US, where the case counts more than tripled from 2010 to 2019. Yet, the highest incidence (0.91 cases per 100,000 people) was reported in 2018.

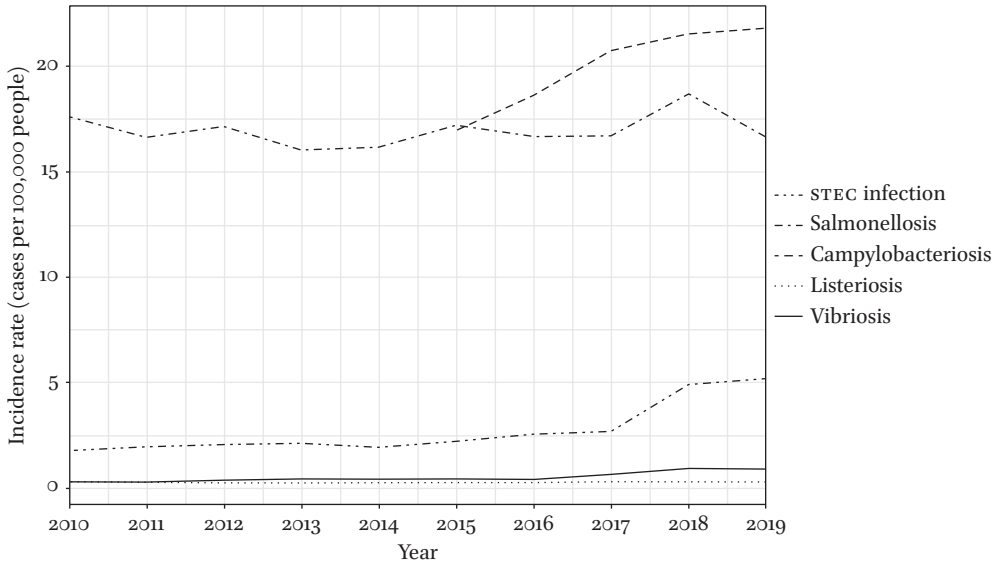


FIGURE 3.1 Incidence of reported cases of zoonotic foodborne diseases in the United States, 2010–2019  
SOURCE: AUTHORS' ELABORATION

## 7 Conclusion

It has been shown that zoonotic FBDS are on the rise in the US and other high-income countries. Although the burden of FBDS is greater in low- and middle-income countries, public health authorities of high-income nations have to be aware of epidemiological trends in order to control and prevent the increase in the IR of these diseases. Measures based on the One Health approach, which considers the human-animal-environment interface, are a way to fully understand the rise in the IR of zoonoses and to effectively develop strategies to mitigate their impact on populations. The limitations in the research of epidemiological trends include the lack of analysis of other zoonotic FBDS such as norovirus infection even though this is not considered a nationally notifiable disease. Although the diseases analyzed are commonly transmitted through the consumption of contaminated food, the proportion of cases that were related to food is not available. Additionally, the comparison of IR between countries was limited as many countries do not have a surveillance system that report data on FBDS on a regular basis. Furthermore, supplementary studies are necessary to evaluate what factors are associated with the increase in IR of zoonotic FBDS in the US and to examine the association between these diseases and food products of animal origin.

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## References

- Abebe, E., Gugsu, G., & Ahmed, M. (2020). Review on major food-borne zoonotic bacterial pathogens. *Journal of Tropical Medicine*, 2020, 4674235. doi:10.1155/2020/4674235.
- Acheson, D., & Hohmann, E. L. (2001). Nontyphoidal salmonellosis. *Clinical Infectious Diseases*, 32(2), 263–269.
- Adell, T., Martín-Durán, J. M., Saló, E., & Cebrià, F. (2015). Platyhelminthes. In *Evolutionary Developmental Biology of Invertebrates 2* (pp. 21–40). Vienna: Springer.
- Agbaje, M., Begum, R. H., Oyekunle, M. A., Ojo, O. E., & Adenubi, O. T. (2011). Evolution of Salmonella nomenclature: a critical note. *Folia Microbiologica*, 56(6), 497–503.
- Ameer, M. A., Wasey, A., & Salen, P. (2021). Escherichia Coli (E Coli 0157 H7). *StatPearls* [Internet]. Treasure Island: StatPearls Publishing. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK507845/>.
- Animal and Plant Health Inspection Service. (2020, June 8). *U.S. identifies its top 8 zoonotic diseases of concern*. U.S. Department of Agriculture. Retrieved August 8, 2021, from [https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/programs/nwrc/sa\\_spotlight/zoonotic\\_diseases\\_of\\_concern](https://www.aphis.usda.gov/aphis/ourfocus/wildlifedamage/programs/nwrc/sa_spotlight/zoonotic_diseases_of_concern).
- Baker-Austin, C., Oliver, J. D., Alam, M., Ali, A., Waldor, M. K., Qadri, F., & Martinez-Urtaza, J. (2018). Vibrio spp. infections. *Nature Reviews Disease Primers*, 4(1), 1–19.
- Ballem, A., Gonçalves, S., Garcia-Meniño, I., Flament-Simon, S. C., Blanco, J. E., Fernandes, C., Saavedra, M. J., Pinto, C., Oliveira, H., Blanco, J., Almeida, G., & Almeida, C. (2020). Prevalence and serotypes of Shiga toxin-producing Escherichia coli (STEC) in dairy cattle from Northern Portugal. *Plos One*, 15(12), e0244713.
- Bhunia, A. K. (2018a). *Foodborne microbial pathogens: mechanisms and pathogenesis*. Springer.
- Bhunia, A. K. (2018b). Salmonella enterica. In *Foodborne Microbial Pathogens* (pp. 271–287). New York: Springer.
- Bintsis, T. (2017). Foodborne pathogens. *AIMS microbiology*, 3(3), 529.
- Black, R. E., Levine, M. M., Clements, M. L., Hughes, T. P., & Blaser, M. J. (1988). Experimental Campylobacter jejuni infection in humans. *Journal of infectious diseases*, 157(3), 472–479.
- Bruyand, M., Mariani-Kurkdjian, P., Gouali, M., De Valk, H., King, L. A., Le Hello, S., Bonacorsi, S., & Loirat, C. (2018). Hemolytic uremic syndrome due to Shiga toxin-producing Escherichia coli infection. *Medecine et Maladies Infectieuses*, 48(3), 167–174.

- Byrne, L., Jenkins, C., Launders, N., Elson, R., & Adak, G. K. (2015). The epidemiology, microbiology and clinical impact of Shiga toxin-producing *Escherichia coli* in England, 2009–2012. *Epidemiology & Infection*, 143(16), 3475–3487.
- Castro, V. S., Carvalho, R. C. T., Conte-Junior, C. A., & Figueiredo, E. E. S. (2017). Shiga-toxin producing *Escherichia coli*: pathogenicity, supershedding, diagnostic methods, occurrence, and foodborne outbreaks. *Comprehensive Reviews in Food Science and Food Safety*, 16(6), 1269–1280.
- Centers for Disease Control and Prevention. (2014, December 1). *E. coli (Escherichia coli): Questions and answers*. Retrieved August 5, 2021, from <https://www.cdc.gov/ecoli/general/index.html>.
- Centers for Disease Control and Prevention. (2018, November 5). *Burden of foodborne illness: Findings*. Retrieved August 8, 2021, from <https://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html>.
- Centers for Disease Control and Prevention. (2019a, November 13). *Information for healthcare professionals and laboratories*. Retrieved August 9, 2021, from <https://www.cdc.gov/salmonella/general/technical.html>.
- Centers for Disease Control and Prevention. (2019b, December 5). *Salmonella: Diagnostic and public health testing*. Retrieved August 2, 2021, from [https://www.cdc.gov/salmonella/general/diagnosis-treatment.html?CDC\\_AA\\_refVal=https%3A%2F%2Fwww.cdc.gov%2Fsalmonella%2Fgeneral%2Fdiagnosis.html](https://www.cdc.gov/salmonella/general/diagnosis-treatment.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fsalmonella%2Fgeneral%2Fdiagnosis.html).
- Centers for Disease Control and Prevention. (2019c, December 20). *Guillain-Barré syndrome*. Retrieved August 5, 2021, from <https://www.cdc.gov/campylobacter/guillain-barré.html>.
- Centers for Disease Control and Prevention. (2020, February 3). *Zoonotic disease prioritization*. Retrieved August 1, 2021, from [https://www.cdc.gov/onehealth/what-we-do/zoonotic-disease-prioritization/us-workshops.html?CDC\\_AA\\_refVal=https%3A%2F%2Fwww.cdc.gov%2Fonehealth%2Fdomestic-activities%2Fus-ohzdp.html](https://www.cdc.gov/onehealth/what-we-do/zoonotic-disease-prioritization/us-workshops.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fonehealth%2Fdomestic-activities%2Fus-ohzdp.html).
- Choudhary, P., Punia, A., Dahiya, S., Sharma, N., Balhara, M., Dangi, M., & Chhillar, A. K. (2021). Recent Trends in Diagnosis of *Campylobacter* Infection. In S. K. Gahlawat, S. Maan. *Advances in Animal Disease Diagnosis*, New York: CRC Press, 219–228.
- Coburn, B., Grassl, G. A., & Finlay, B. B. (2007). *Salmonella*, the host and disease: a brief review. *Immunology and Cell Biology*, 85(2), 112–118.
- Croxen, M. A., Law, R. J., Scholz, R., Keeney, K. M., Wlodarska, M., & Finlay, B. B. (2013). Recent advances in understanding enteric pathogenic *Escherichia coli*. *Clinical Microbiology Reviews*, 26(4), 822–880.
- Desmarchelier, P., Fegan, N. (2011). Pathogens in milk *Escherichia coli*. In J. W. Fuquay, P. McSweeney, P. Fox. (Eds). *Encyclopedia of Dairy Sciences*. 2nd ed. London: Academic Press, 60–66.
- Doyle, M. P., Diez-Gonzalez, F., & Hill, C. (Eds.) (2019). *Food microbiology: fundamentals and frontiers*. John Wiley & Sons.

- Economic Research Service. (2021, March 10). *Cost estimate of foodborne illnesses*. U.S. Department of Agriculture. Retrieved July 29, 2021, from <https://www.ers.usda.gov/data-products/cost-estimates-of-foodborne-illnesses/>.
- Esson, D., Mather, A. E., Scanlan, E., Gupta, S., De Vries, S. P., Bailey, D., Harris, S. R., McKinley, T. J., Méric, G., Berry, S. K., Mastroeni, P., Sheppard, S. K., Christie, G., Thompson, N. R., Parkhill, J., & Grant, A. J. (2016). Genomic variations leading to alterations in cell morphology of *Campylobacter* spp. *Scientific reports*, 6(1), 1–13.
- Etcheverria, A. I., & Padola, N. L. (2013). Shiga toxin-producing *Escherichia coli*: factors involved in virulence and cattle colonization. *Virulence*, 4(5), 366–372.
- European Food Safety Authority. (n.d.). *Foodborne zoonotic disease*. Retrieved July 28, 2021, from <https://www.efsa.europa.eu/en/topics/topic/foodborne-zoonotic-diseases>.
- Facciola, A., Riso, R., Avventuroso, E., Visalli, G., Delia, S. A., & Laganà, P. (2017). *Campylobacter: from microbiology to prevention*. *Journal of preventive medicine and hygiene*, 58(2), E79.
- Fitzgerald, C., & Nachamkin, I. (2015). *Campylobacter and arcobacter*. *Manual of clinical microbiology*, 998–1012.
- Givens, C. E., Bowers, J. C., DePaola, A., Hollibaugh, J. T., & Jones, J. L. (2014). Occurrence and distribution of *Vibrio vulnificus* and *Vibrio parahaemolyticus* – potential roles for fish, oyster, sediment and water. *Letters in applied microbiology*, 58(6), 503–510.
- Godfray, H. C. J., & Garnett, T. (2014). Food security and sustainable intensification. *Philosophical transactions of the Royal Society B: biological sciences*, 369(1639), 20120273.
- Gould, L. H., & STEC Clinical Laboratory Diagnostics Working Group. (2012). Update: recommendations for diagnosis of Shiga toxin-producing *Escherichia coli* infections by clinical laboratories. *Clinical Microbiology Newsletter*, 34(10), 75–83.
- Government of Canada. (2012, April 30). *Pathogen safety data sheet – infectious substances*. Retrieved August 8, 2021, from <https://www.canada.ca/en/public-health/services/laboratory-biosafety-biosecurity/pathogen-safety-data-sheets-risk-assessment/listeria-monocytogenes.html>.
- Grimont, P. A., & Weill, F. X. (2007). Antigenic formulae of the *Salmonella* serovars. *WHO collaborating centre for reference and research on Salmonella*, 9, 1–166.
- Gwida, M. M., & Al-Ashmawy, M. A. (2014). Culture versus PCR for *Salmonella* species identification in some dairy products and dairy handlers with special concern to its zoonotic importance. *Veterinary medicine international*, 2014.
- Hernandez-Milian, A., & Payeras-Cifre, A. (2014). What is new in listeriosis?. *BioMed research international*, 2014.
- Jamshidi, A., & Zeinali, T. (2019). Significance and characteristics of *Listeria monocytogenes* in poultry products. *International journal of food science*, 2019.
- Janssen, R., Krogfelt, K. A., Cawthraw, S. A., Van Pelt, W., Wagenaar, J. A., & Owen, R. J. (2008). Host-pathogen interactions in *Campylobacter* infections: the host perspective. *Clinical microbiology reviews*, 21(3), 505–518.

- John, D. T., & Petri, W. A. (2020). *Markell & Voge's Medical Parasitology-10th Sea Ed.* Elsevier (Singapore) Pte Limited.
- Joint, F. A. O., & World Health Organization. (1959). *Joint WHO/FAO Expert Committee on Zoonoses [meeting held in Stockholm from 11 to 16 August 1958]: second report.*
- Jones, B. A., Grace, D., Kock, R., Alonso, S., Rushton, J., Said, M. Y., McKeever, D., Mutua, F., Young, J., McDermott, J., & Pfeiffer, D. U. (2013). Zoonosis emergence linked to agricultural intensification and environmental change. *Proceedings of the National Academy of Sciences*, 110(21), 8399–8404.
- Kokashvili, T., Whitehouse, C. A., Tskhvediani, A., Grim, C. J., Elbakidze, T., Mitaishvili, N., Janelidze, N., Jaiani, E., Haley, B. J., Lashkhi, N., Huq, A., Colwell, R. R., & Tediashvili, M. (2015). Occurrence and diversity of clinically important *Vibrio* species in the aquatic environment of Georgia. *Frontiers in public health*, 3, 232.
- Kuchenmüller, T., Abela-Ridder, B., Corrigan, T., & Tritscher, A. (2013). World Health Organization initiative to estimate the global burden of foodborne diseases. *Rev Sci Tech*, 32(2), 459–467.
- Le Loir, Y., Baron, F., & Gautier, M. (2003). [i] *Staphylococcus aureus* [/i] and food poisoning. *Genetics and molecular research: GMR*, 2(1), 63–76.
- Liu, D. (Ed.). (2018). *Handbook of foodborne diseases.* CRC Press.
- Long, S. S., Prober, C. G., & Fischer, M. (2017). *Principles and practice of pediatric infectious diseases E-Book.* Elsevier Health Sciences.
- Mahmud, R., Lim, Y. A. L., & Amir, A. (2017). Protozoa and Helminths. In *Medical Parasitology* (pp. 3–4). Cham: Springer.
- Man, S. M. (2011). The clinical importance of emerging *Campylobacter* species. *Nature Reviews Gastroenterology & Hepatology*, 8(12), 669–685.
- McLinden, T., Sargeant, J. M., Thomas, M. K., Papadopoulos, A., & Fazil, A. (2014). Component costs of foodborne illness: a scoping review. *BMC Public Health*, 14(1), 1–12.
- McNeill, C., Sisson, W., & Jarrett, A. (2017). Listeriosis: A resurfacing menace. *The Journal for Nurse Practitioners*, 13(10), 647–654.
- Murrell, K. D. (2013). Zoonotic foodborne parasites and their surveillance. *Rev Sci Tech*, 32(2), 559–569.
- Nataro, J. P., & Kaper, J. B. (1998). Diarrheagenic *Escherichia coli*. *Clinical Microbiology Reviews*, 11(1), 142–201.
- Nwaiwu, O. (2020). What are the recognized species of the genus *Listeria*? *Access Microbiology*, 2(9), e000153.
- Office of Disease prevention and Health Promotion. (2021, June 23). *Food safety: Objectives.* HealthyPeople. Culture versus PCR for *Salmonella* species identification in some dairy products and dairy handlers with special concern to its zoonotic importance. Retrieved August 2, 2021, from <https://www.healthypeople.gov/2020/topics-objectives/topic/food-safety/objectives>.



- Petro, C. D., Trojnar, E., Sinclair, J., Liu, Z. M., Smith, M., O'Brien, A. D., & Melton-Celsa, A. (2019). Shiga toxin type 1a (Stx1a) reduces the toxicity of the more potent Stx2a in vivo and in vitro. *Infection and Immunity*, 87(4), e00787–18.
- Phillips, J. A. (2021). The One Health Framework. *Workplace Health & Safety*, 69(4), 188–188.
- Raszl, S. M., Froelich, B. A., Vieira, C. R. W., Blackwood, A. D., & Noble, R. T. (2016). *Vibrio parahaemolyticus* and *Vibrio vulnificus* in South America: water, seafood and human infections. *Journal of Applied Microbiology*, 121(5), 1201–1222.
- Rohr, J. R., Barrett, C. B., Civitello, D. J., Craft, M. E., Delius, B., DeLeo, G. A., Hudson, P. J., Jouanard, N., Nguyen, K. H., Ostfeld, R. S., Remais, J. V., Riveau, G., Sokolow, S. H., & Tilman, D. (2019). Emerging human infectious diseases and the links to global food production. *Nature Sustainability*, 2(6), 445–456.
- Schmidt, T. M. (Ed.). (2019). *Encyclopedia of Microbiology*. Amsterdam, Oxford, Cambridge, MA: Academic Press.
- Serventi, L., Curi, B., Johns, R., Silva, J., Bainbridge, R., & Gaither, K. (2020). Pregnancy Complicated by *Listeria Monocytogenes*: A Case Report and Review of the Literature. *Journal of the National Medical Association*, 112(4), 428–432.
- Siddiqui, S., & Yuan, J. (2021). Binding Characteristics Study of DNA based Aptamers for *E. coli* O157:H7. *Molecules*, 26(1), 204.
- Silva, J., Leite, D., Fernandes, M., Mena, C., Gibbs, P. A., & Teixeira, P. (2011). *Campylobacter* spp. as a foodborne pathogen: a review. *Frontiers in microbiology*, 2, 200.
- Singleton, W. (2018). *Invertebrate reproduction and development*. Scientific e-Resources.
- Stein, R. A., & Chirilă, M. (2017). Routes of transmission in the food chain. In *Foodborne Diseases* (pp. 65–103). Academic Press.
- The Center for Food Security & Public Health. (2013). *Salmonellosis: Paratyphoid, nontyphoidal salmonellosis*. Retrieved July 30, 2021, from [https://www.cfsph.iastate.edu/Factsheets/pdfs/nontyphoidal\\_salmonellosis.pdf](https://www.cfsph.iastate.edu/Factsheets/pdfs/nontyphoidal_salmonellosis.pdf).
- Tian, K., Chen, X., Luan, B., Singh, P., Yang, Z., Gates, K. S., Lin, M., Mustapha, A., & Gu, L. Q. (2018). Single locked nucleic acid-enhanced nanopore genetic discrimination of pathogenic serotypes and cancer driver mutations. *ACS nano*, 12(5), 4194–4205.
- Travert, B., Rafat, C., Mariani, P., Cointe, A., Dossier, A., Coppo, P., & Joseph, A. (2021). Shiga Toxin-Associated Hemolytic Uremic Syndrome: Specificities of Adult Patients and Implications for Critical Care Management. *Toxins*, 13(5), 306.
- United States Department of Health and Human Services. (n.d.). *National notifiable diseases surveillance system (NNDSS)*. HealthyPeople. Retrieved August 6, 2021, from <https://health.gov/healthypeople/objectives-and-data/data-sources-and-methods/data-sources/national-notifiable-diseases-surveillance-system-nndss>.
- United States Food and Drug Administration. (2018, January 29). *Hazard analysis critical control point (HACCP)*. Retrieved August 1, 2021, from <https://www.fda.gov/food/guidance-regulation-food-and-dietary-supplements/hazard-analysis-critical-control-point-haccp>.

- Vivant, A. L., Garmyn, D., & Piveteau, P. (2013). *Listeria monocytogenes*, a down-to-earth pathogen. *Frontiers in cellular and infection microbiology*, 3, 87.
- Wang, S., & Orsi, R. H. (2013). *Listeria*. In *Foodborne infections and intoxications* (pp. 199–216). Academic Press.
- World Health Organization. (n.d.). *Disability-adjusted life years (DALYs)*. Retrieved July 29, 2021, from <https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158>.
- World Health Organization. (2012, January 17). *Neglected tropical diseases*. Retrieved July 27, 2021, from <https://www.who.int/news-room/q-a-detail/neglected-tropical-diseases>.
- World Health Organization. (2015). *WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007–2015*. World Health Organization.
- World Health Organization. (2018a, February 7). *E. coli*. Retrieved August 3, 2021, from <https://www.who.int/news-room/fact-sheets/detail/e-coli>.
- World Health Organization. (2018b, February 20). *Listeriosis*. Retrieved August 8, 2021, from <https://www.who.int/news-room/fact-sheets/detail/listeriosis>.
- World Health Organization. (2020a, April 30). *Food safety*. Retrieved July 29, 2021, from <https://www.who.int/news-room/fact-sheets/detail/food-safety>.
- World Health Organization. (2020b, May 1). *Campylobacter*. Retrieved July 17, 2021, from <https://www.who.int/news-room/fact-sheets/detail/campylobacter>.
- Yaeger, R. G. (1996). Protozoa: structure, classification, growth, and development. In S. Baron (Ed.), *Medical microbiology*. (4th ed.). University of Texas Medical Branch at Galveston.
- Zhao, X., Lin, C. W., Wang, J., & Oh, D. H. (2014). Advances in rapid detection methods for foodborne pathogens. *Journal of Microbiology and Biotechnology*, 24(3), 297–312.



**PART 2**

*Determinants of Public Health Outcomes*





# Institutional Analysis of Healthcare Systems in Selected Developed Countries

*Julian Smółka*

## Abstract

The aim of this chapter is to search for common institutional traits that improve the efficiency of healthcare systems in developed countries. The study joins the broad discussion on the topic of limiting costs and accelerating effects of healthcare systems. An extensive review of the literature and statistical sources is used to create the institutional framework for healthcare systems in the United States, the United Kingdom, Germany, Sweden, Singapore, and Poland – developed countries selected for differences in socio-economic conditions of health care as well as diverse models of capitalism. Based on the characteristics specified during research, a comparative analysis of institutional traits was performed. This allowed the identification of similarities that improve the efficiency of healthcare systems in developed countries (as measured by the provision of satisfactory services at acceptable levels of cost). The institutional traits and patient navigation within the healthcare systems of Singapore and Sweden appear to be most effective in increasing system efficiency. Other selected features from the remaining countries were also brought up. Wide implementation of the presented institutional traits may help reduce the burden of health care costs while maintaining high quality services.

## Keywords

healthcare systems – efficiency – United States – United Kingdom – Germany – Sweden – Singapore – Poland

## 1 Introduction

The World Health Organization defines the health system as all the activities whose primary purpose is to promote, restore and maintain health (WHO, 2000, p. 5). However, this broad definition is not applicable when studying and comparing the systems of individual countries; hence, this chapter deals with the healthcare system, meaning one providing medical care, as it is also understood in everyday language (Libura et al., 2018, p. 11).

The primary goal of the healthcare system is to ensure an appropriate scope and level of health services that the state provides guided by concern for public health. This is because health is not only an individual value, but it also constitutes a social resource that guarantees the long-term development of a community (Frączkiewicz-Wronka, 2009).

Demographic and epidemiological changes, as well as technological progress, pose new challenges to the healthcare system. An aging population, rising costs of chronic disease management, and expectations of access to new medical technologies also give rise to pressure for increased funding and better quality of services, to which the state, with its limited resources in the face of unlimited needs, must somehow respond (Libura et al., 2018, p. 7). The following chapter was born out of the question of what that response should look like.

There is no doubt about what a healthcare system should be: accessible, cost-effective, and enabling the use of modern therapies and treatments. However, there is no consensus on what a system that achieves all these expected components should exactly look like. The aim of this chapter is an institutional analysis of healthcare systems in six selected developed countries in order to point out the advantages and disadvantages of the solutions found in each of them and, on this basis, formulate conclusions about the best practices in shaping health care.

For the purposes of this analysis, the selected countries are overviewed in terms of specific socio-economic input and output measures, while characterizing their healthcare systems. Then, by comparing the parameters of each system, an attempt is made to compare them and select the best replicable elements.

This article claims that that the institutional analysis of individual countries will show that the most effective healthcare traits include its public nature (Basu et al., 2012), with decentralized decision-making based on centrally defined processes (James et al., 2019), a central patient registry for knowledge management and extensive research (Gliklich, Dreyer, & Leavy, 2014), and

elements of competition between different institutions (Barros et al., 2016) with an extensive ecosystem of cooperation. Digitalization is also believed to be an additional element which plays an increasingly important role.

## 2 Theoretical Overview

For a complete analysis of healthcare systems, it is necessary to understand the models on which they are based, as well as their historical, cultural, and social conditions.

### 2.1 *Theoretical Healthcare Models and Their Historical Context*

The literature usually distinguishes four models of healthcare. Three of them, although their roots go back as far as the 19th century, still represent an ideal/typical model for contemporary solutions (Beveridge, Bismarck, and residual), and the fourth, although strictly historical in nature (Semashko), is still a source of inspiration for decision-makers in shaping health care (Suchecka, 2010, p. 46). Some sources also mention separately the National Health Insurance Model, which is a combination of the Beveridge and Bismarck models, but due to the lack of independent elements distinguishing them from the other models, it is not the subject of analysis here (Chung, 2017).

The Bismarck Model (public contract model), was the first universal healthcare model. Introduced in 1883 by Reich Chancellor Otto von Bismarck, revolutionary in its nature, it established compulsory health insurance (Łagowski, 2012, pp. 82–83).

The Beveridge Model (public integrated model) was introduced in the United Kingdom in 1948 based on William Beveridge's report "Social Insurance and Allied Services" (Beveridge, 1942). It combines elements of universal health coverage with a public guarantee of access to health care. Underlying the system is the belief that health is a human right (Chung, 2017).

The residual model (a private insurance provider, mixed system) is based on private health insurance and is market-based. The majority of entities involved in the system operate on for-profit basis – the model provides for domination of the private sector. In most cases, the costs of services are covered by insurance institutions; if there is no insurance, the patient has to cover the costs. This rule does not apply to certain categories of people (e.g. disabled persons and veterans) who are covered by public programs (Białynicki-Birula, 2010, p. 4). The only developed country in which such a system exists today is the United States.



The Semashko model (central planning model – historical) of primary healthcare was introduced as a result of the October Revolution of 1917 in the Soviet Union. It was based on five-year plans of the central apparatus responsible for coordinating all system activities, starting with financing, creating and managing infrastructure, and training medical personnel (Libura et al., 2018, p. 13). From the 1950, Semashko's model began to be implemented in different versions in other countries, mainly under the rule of “people's power”.

The abovementioned model solutions are not used nowadays in their pure form in any developed country, which is a result of continuous social and cultural changes, as well as an ongoing reform of healthcare systems around the world, as if in response to the pressure mentioned in the introduction to this chapter.

TABLE 4.1 Characteristics of theoretical healthcare models

Beveridge	Model		
	Bismarck	Residual	Semashko
<ul style="list-style-type: none"> <li>– treating diseases as <i>sui generis</i> social risks, where effects are limited by spreading the risk over wider social groups (co-insured), according to the principle of social solidarity</li> <li>– financing based on obligatory contributions for employers and employees, supplemented by state budget subsidies</li> <li>– managed by institutions independent from the government, e.g. health funds</li> <li>– contracting of services</li> </ul>	<ul style="list-style-type: none"> <li>– financing of the health care sector by the state budget, from general taxes</li> <li>– full control of the system by the government and its field agencies</li> <li>– full accessibility for all citizens</li> <li>– participation of patients in the costs</li> <li>– private sector participation</li> </ul>	<ul style="list-style-type: none"> <li>– domination of the private sector</li> <li>– health services are treated as goods purchased in a transactional system</li> <li>– in most cases, the costs of services are covered by insurance institutions, if not – out of the pocket</li> </ul>	<ul style="list-style-type: none"> <li>– financing by the state budget</li> <li>– full control of the system by the government,</li> <li>– full availability of health services</li> <li>– staff employed based on state allocations and paid according to the pay scale</li> </ul>

SOURCE: AUTHOR'S ELABORATION

## 2.2 *Contemporary Models of Healthcare*

The models presented in Section 2.1 are predecessors to the contemporary ones and much has changed in the study of health systems since their inception. It has been shown that health plays an important role in the creation of the welfare state, and this role has been steadily increasing for many years. This was the view of renowned Danish sociologist Gøsta Esping-Andersen – author of the most famous classification of welfare states presented in his book “The Three Worlds of Welfare Capitalism” (1990). His work became the basis for numerous subsequent studies on the empirical classification of healthcare systems. In 2000, to emphasize the role played by health in the welfare state, Michael Moran (Moran, 2000) proposed the term “health-care state”, which was supposed to show its inherent connection with the “welfare state”. He also analyzed the direction in which healthcare systems are changing and proposed a new classification of them into four “families”:

- entrenched command and control states,
- supply states,
- corporatist states,
- insecure command and control states.

The name of the first “command and control” family is taken from the work of Saltman and von Otter (1992). Moran calls it “entrenched” because in the family of states considered here (which includes Scandinavia and the United Kingdom) the institutions of command and control are well established. The state plays a dominant role on both the “production” and “consumption” sides. It holds a vast majority of the means of production are in its hands. Decisions are made by democratically elected decision-makers at national (UK), state and regional (Sweden, Denmark, Norway), or national and municipal (Finland) levels. The state uses its power to manage resources through the tax system and allocates the resources raised through administrative mechanisms. The only area in which the state has relatively little involvement is the technology sector, which, however, is strongly supported by the regulatory and institutional framework.

The “supply states” family actually consists of one country – the United States. The source of this system is quite easy to reconstruct. An extensive private system arose naturally so quickly and its structures became so stagnant that by the time the foundations of modern healthcare systems were being laid in Europe, it was already difficult to change anything in the States. In the early stages, before Medicaid and Medicare, the state focused on financing the construction of hospitals and on research activities. This contributed to the emergence of the best scientific community in the world, but the rampant costs of the system make medical care extremely far from universal.

The corporatist system, of which Germany is the best example, relies on a relatively minor role of the state, which is limited to providing a public legal framework, while real decisions largely fall within the remit of corporations, which dominate the medical technology sector, or physicians' associations, which own the real decision-making process in matters of outpatient care, for example. However, there is growing public pressure to change this, and action is being taken to do so, so one can conclude that if the German model of such system is changing, it is possible that similar systems will also be displaced.

The family of "insecure command and control systems" is a recent creation. It consists of four remarkably similar Mediterranean countries: Portugal, Italy, Greece, and Spain. Their healthcare systems are based on the same foundations as those of the "entrenched command and control" family and were modeled on them. In none of the countries, however, have the systems been rooted in the Northern European model. In all of the "insecure" systems, despite the existence of a formal set of citizenship-based health entitlements, there is in fact no universal health coverage. In Portugal and Greece, the system has never succeeded in crowding out the large private insurance sector. In Italy, fiscal pressures have significantly weakened the universal system to the point where co-payments (which are marginal in most European systems) have become the largest single source of funding for the system. Despite formal guarantees of public health care, many services continue to be offered privately. This also applies to the most problematic group in this regard, namely physicians, who in large part run private practices. This is largely due to a distinct culture that is not entirely characterized by Weberian administrative rationality (Moran, 2000, pp. 138–158).

Little seems to have changed in this area since 2000, when Moran proposed his classification, and his observations and diagnoses remain valid. The reader will be able to see some of this in the next part of this chapter.

### 3 Characteristics of Selected Countries and Healthcare Systems

For the purposes of this chapter, the analysis has been narrowed down to six selected developed countries. This is due primarily to the desire to maintain the clarity of the argument, as well as the article word count limit. By adopting the assumed differentiation criteria, the comparison can reflect the global situation of the healthcare systems in developed countries and allows the

determination of the directions in which they should move to achieve the highest degree of efficiency.

Based on a review of theoretical and contemporary models of healthcare systems, discussed in the first part of the chapter, an attempt has been to select countries so as to best reflect the totality of their diversity. Guided primarily by the criteria of the healthcare system in place, the expenditures it incurs and its effectiveness, the following countries have been selected on the basis of my own analysis:

1. United States of America
2. United Kingdom
3. Singapore
4. Germany
5. Sweden
6. Poland

As part of the discussion on the individual countries selected for analysis, the categorized criteria related to the healthcare system have been compiled and compared. The measures and data analyzed and compared are presented in Table 4.2.

TABLE 4.2 The characteristics of healthcare systems of the selected developed countries

Indicator/country	USA	United Kingdom	Singapore	Germany	Sweden	Poland	
Socioeconomic situation	GDP (US\$ millions)	20,523	3,121	555	4,473	547	1,256
	GDP per capita (US\$)	62,526	46,699	97,341	53,815	53,205	33,086
	Population (millions)	328.23	66.83	5.7	83.13	10.28	37.97
	Unemployment rate (3-year average) in %	3.97	4.02	4.11	3.43	6.63	4.00
	Inflation rate (3-year average) in %	2.12	2.19	0.52	1.56	1.84	2.03
	Gini coefficient	0.414	0.348	0.352	31.9	28.8	29.7
	Budget deficit (% of GDP)	-6.58%	-2.07%	-0.3%	1.44%	0.49%	-0.74%
	Public sector debt (% of GDP)	135.26%	116.56%	126.3%	69.12%	55.63%	63.62%

TABLE 4.2 The characteristics of health care systems of the selected developed countries (*cont.*)

Indicator/country	USA	United Kingdom	Singapore	Germany	Sweden	Poland	
Healthcare	Number of doctors per 10K inhabitants	26.12	27.86 – UK	22.94	42.49	39.84	23.79
	Number of nurses and midwives per 10K inhabitants	145.5	81.72	62.43	132.4	118.2	68.93
	Number of hospitals	6,146	1,257	28	3,084	100	949
	Number of hospital beds per 1K inhabitants	2.9	2.8	2.4	8.3	2.6	6.5
	Number of recruiting clinical trials	20,667	955	235	1,354	305	603
	Clinical trials market value	\$20.4 bn	€5679 m	n/d	€6,227 m	€1,104 m	€289 m
	Inputs	Expenditure on health care [% GDP]	17.1%	9.6%	4.40%	11.20%	11%
Expenditure on health care per capita (US\$ PPP)		10,246	4,338	4,269	5592	5699	1958
Share of health care financing in total budget expenditures		22.60%	18.70%	12.60%	19.90%	18.70%	10.90%
Outputs	Life expectancy at birth (years)	78.5	81.4	83	81	82.4	77.75
	% of people satisfied with health care	30%	53%	60%	39%	34%	13%

SOURCE: AUTHOR'S ELABORATION

### 3.1 *United States of America*

The healthcare system in the US is an example of a residual healthcare financing model. Private financing plays a key role in the structure of the US healthcare system. The system is among the most expensive as well as the most complex in the world (Lewandowski, 2010, p. 64). Healthcare is the most regulated sector in the US (Owoc et al., 2009), which translates into extraordinarily

high administrative costs, estimated to be as high as 30% of total health care costs (Cutler, 2018, p. 2) – twice as much as is spent on heart disease treatment and three times as much as on cancer treatment (Cutler, Wikler, & Basch, 2012, p. 1876).

In 2018, 90.6% of the US population had some form of insurance coverage; the number of uninsured was 30.7 million (CMS, 2019b). However, it is important to keep in mind that even among the insured, in many cases the amount of insurance is insufficient to cover major health expenses.

In 2017, US health care spending grew 4.6%, reaching \$3.6 trillion (\$11,172 per capita) in 2018. The increase was 0.4 percentage points faster than in the previous year and more than double the average growth rate of 1.9% per year between 2000 and 2017. Health spending as a share of GDP was at 17.7%, falling by 0.2 p.p. y-o-y.

The share of health spending in total budget expenditures was 22.6% in 2017, as much as 6.4 p.p. higher than in 2000. This shows how large and growing a burden the healthcare system is on the US budget.

The US spends the most on hospital treatment, on which as much as every third dollar is spent. A large share is also spent on specialist services (20%), as well as funds allocated to drugs, on which the US spends the most in the world in absolute terms (Statista, 2019).

The healthcare system in the US is one of the most expensive and inefficient in the world (Kumar, Ghildayal, & Shah, 2011, p. 366). The country is notable for having shorter life expectancy, a higher suicide rate, and more than twice the rate of obesity and long-term disease burden relative to the OECD average (Tikkanen & Abrams, 2020).

US residents are among the most dissatisfied with their healthcare system among developed countries in the world. An IPSOS survey from late 2019 shows that 30% are satisfied with the current system, 25% are neither satisfied nor dissatisfied, and as many as 43% express dissatisfaction (IPSOS, 2020).

### 3.2 *United Kingdom*

The UK healthcare system based on the Beveridge model consists *de facto* of four separate healthcare systems: National Health Service in England, Health, Social Services and Public Safety in Northern Ireland, NHS Scotland, and NHS Wales.

In each of the UK countries, the NHS has its own distinct structure and organization. The system consists of two broad parts: one dealing with strategy, policy and management, and the other with actual medical care, which is divided in turn into primary (community care, GPs, dentists, pharmacists,

etc.), secondary (hospital care available by GP referral), and tertiary (specialist hospitals). The distinction between these two parts has become clearer over the years (Grosios, Gahan, & Burbidge, 2010, p. 529).

The UK government sets the total budget for the NHS in England, which includes subsidies for the other three countries, where their legislatures determine how much of that subsidy can be spent on healthcare (Tunstall, 2016).

In 2018, healthcare spending in the UK was £214.4 billion, equating to £3,227 spent per person. This spending represents 10% of the UK's GDP in 2018 and its share of GDP increased by 0.2 p.p. from the previous year, which was due to healthcare spending growing faster than GDP. Between 1997 and 2018, health spending grew at a nominal annual rate of 5.8%.

The Department of Health and Social Care (DHSC) is the main funder of healthcare in the UK. For 2019/20, the largest part of its budget, £121 billion, was allocated to the NHS in England, with the remaining £17 billion split between other DHSC agencies and programs.

The healthcare system in the UK is considered relatively efficient, achieving average health outcomes with moderate expenditure. Depending on the set of selected indicators, it ranks either slightly above or slightly below the average efficiency among developed countries. The challenges identified earlier create pressure for increased investment and further reforms to maintain current performance (Papanicolas et al., 2019, p. 11). The strengths of the UK's institutional healthcare ecosystem include a highly developed clinical research sector, in which the UK is one of the global leaders.

It is worth noting that a majority of UK residents (51%) believe the NHS wastes resources, with only 7% believing it never does. 37% believe that, in general, the UK health system does not waste resources (Gershlick, Charlesworth, & Taylor, 2015, p. 18). In another survey, 69% cited the creation of the NHS in 1948 as the greatest British achievement in history (Duncan & Jowit, 2018).

The NHS faces a number of financial and demand challenges, largely as a consequence of a growing and ageing population, and the rising cost of new drugs and treatments. This primarily translates into greater strain on hospitals and longer waiting times for tests and treatment (Powell, 2020, p. 11). Interestingly, awareness of the worsening situation is not widespread. In a 2015 survey, 43% of respondents agreed that the situation in the healthcare system had not changed significantly over the past 5 years, and improvement and deterioration were indicated by almost equal portions of the population – 26% of the respondents diagnosed the situation as better and much better, 28% as worse and much worse (Gershlick, Charlesworth, & Taylor, 2015, p. 13).

A vast majority of UK respondents agree with the current formula of the health system as being tax-funded, free at the point of use, and providing comprehensive

medical care for all citizens (Gershlick, Charlesworth, & Taylor, 2015, p. 10). This translates into high rankings in satisfaction – the UK is ranked 4th in the world with 53% of residents satisfied with the current form of the system, 24% neither satisfied nor dissatisfied and 22% dissatisfied (IPSOS, 2020).

### 3.3 *Singapore*

Singapore's healthcare system is one of a mixed type, in which the organizing role is assigned to the government, but the state's main safety net program, MediShield Life, only covers large bills for inpatient care and some outpatient procedures. Supplementing MediShield Life are government subsidies, as well as a mandatory medical savings account called MediSave, which can help residents pay for inpatient care and selected outpatient services. In addition, individuals can purchase additional private health insurance or obtain it through their employer.

A central tenet of Singapore's healthcare system is the belief that all stakeholders share responsibility for achieving sustainable and universal health insurance coverage. Singapore's healthcare framework is multi-layered, where a single procedure may be captured in several systems and have several payers, often overlapping. The overall system, commonly referred to as the 3Ms, is based on three programs:

- MediShield Life: a mandatory health insurance program for citizens and permanent residents that provides lifetime medical care and coverage for high-cost hospital stays and selected outpatient procedures.
- MediSave: a medical savings program to help cover out-of-pocket payments. Contributions to MediSave are mandatory for all citizens and permanent residents in the amount of 8.5–10% of salary depending on age. The individual accounts in which the premiums are held are tax-free and interest-bearing, and the funds in them can only be used to pay for the health care expenses of the insured and their family.
- MediFund: a government fund to cover medical expenses for poor residents whose medical costs are not covered by the funds accumulated in their MediSave accounts.

Singapore is among the countries that spend the least on the health system. In 2017, it was only 4.44% of GDP, which is the highest historical result, preceded by 7 years of a continuous growth in expenditure. In per capita terms, the result is no longer so low, but it is still not high – in 2017, it was \$4,270 measured in purchasing power parity.

The mixed structure of the health system also translates into the fact that the share of health spending in total budget expenditure is also extremely low. It was only 12.6% in 2017, albeit this share had almost doubled since 2000.



In overall health spending, the share of public spending is also extremely low, accounting for only a third of the total. The remainder consists of spending from private savings, funded by private insurance or charities (Lim, 2017, p. 103).

Singapore's healthcare system is considered one of the most efficient in the world, achieving remarkable health outcomes and treatment efficacy at half the cost of any comparable country (Ramesh & Bali, 2019, pp. 42–45).

In Singapore, the national healthcare system is highly regarded, which is reflected in high satisfaction scores in surveys. As many as 60% of residents are satisfied with their healthcare system, 22% are neither satisfied nor dissatisfied, and only 18% are dissatisfied in some form. This gives Singapore a second place ranking for satisfaction with its healthcare system (IPSOS, 2020). This result is particularly interesting when compared with the results of a 2012 survey in which 72% of Singaporeans indicated that they “cannot afford to get sick due to high medical costs” (Lim, 2017, p. 103).

### 3.4 *Germany*

The German healthcare system is based on the Bismarck model and was the world's first universal health insurance system. Two years after the program was introduced, in 1885, it covered 10% of the population. Over time, the coverage rate of the population increased. Currently, state insurance, which provides coverage for inpatient, outpatient, mental health care and prescription drugs, covers approx. 86% of the population. Individuals earning more than \$68,000 per year can opt out of state health insurance premiums in favor of private insurance – which is then not subsidized in any way (Tikkanen et al., 2020a).

The German healthcare system is complex, and responsibility for it is distributed across different levels of government. Decision-making competencies are traditionally divided between the federal and state levels, with many powers delegated to local government bodies. Health insurance is mandatory for all citizens and permanent residents in the form of either statutory or private insurance (Busse & Blümel, 2014, p. 18). The administration and financing of the healthcare system is handled by regional health insurance funds. The delegation of responsibilities to local authorities ensures better informed decisions adapted to local circumstances but also contributes to a fragmented system structure with a plurality of payers and providers (OECD/European Observatory on Health Systems and Policies, 2019a, p. 22).

Germany boasts the highest rate of hospital beds per capita in the European Union. However, due to the impressive number of more than 3,000 hospitals, services are provided in many small and often under-equipped facilities,

resulting in reduced quality. There is political awareness of the problem and discussions are in progress on changes to move towards increasing the degree of centralization of care and specialization of hospitals (European Commission, 2019).

The primary spending institution in the German healthcare system is a network of health insurance funds financed through general wage contributions (14.6% of salary) and a special additional contribution (averaging 1% of salary) shared between employers and employees. Co-payment mechanisms are an additional source of funding, but these are limited to 28 days of co-payment for inpatient care per year and to 2% of household income (1% for the chronically ill). Persons under 18 years of age are excluded from co-payment mechanisms. Individuals earning more than €62,550 per year can opt out of universal insurance in favor of private insurance. However, this is not subsidized in any way from public funds (Tikkanen et al., 2020a).

The share of healthcare expenditure in total budget expenditure in Germany has remained at a similar relatively high level for more than 20 years, with only a relatively small increase from 17.2% in 2000 to 19.9% recorded in 2017. A similarly small increase is seen in the share of health expenditure in GDP from 9.9% at the beginning of the first decade of the 20th century to 11.2% in 2017. (World Bank, 2020a). Per capita spending has more than doubled over that time from \$2,687 to \$5,923 (World Bank, 2020b), putting Germany in second place in Europe (OECD/European Observatory on Health Systems and Policies, 2019a, p. 10).

The German healthcare system is considered to be moderately effective, given its high expenditures and significant human and infrastructural resources. The costs of the healthcare system in Germany do not fully translate into health outcomes. Elements for improvement include reducing avoidable hospital admissions that generate high costs without translating into health outcomes (OECD/European Observatory on Health Systems and Policies, 2019a, p. 14).

Germany is around the middle of the ranking among all countries surveyed in terms of satisfaction with its healthcare system. 39% are satisfied with its current design, a third are neither satisfied nor dissatisfied, and 26% express dissatisfaction (IPSOS, 2020).

### 3.5 *Sweden*

The Swedish healthcare system is universal, and coverage is automatic. The organizational structure is highly decentralized and has three levels:

1. the national level, where the Ministry of Health and Social Policy is responsible for shaping health policy and allocating resources among government agencies and the country's regions;

2. the regional level, where 21 regional bodies are responsible for financing and delivering health services;
3. the local level, where 290 local government bodies are responsible for elderly and disability care (Tikkanen et al., 2020b).

Local and regional authorities at the national level are represented by the Swedish Association of Local Authorities and Regions (SALAR).

The decentralization of the Swedish healthcare system contributes to regional differences in access to care and outcomes across regions, which is contrary to the goal of equality of access to health care in Sweden. In an effort to change this situation, additional funding has been introduced in recent years to reduce these disparities and to improve access in rural areas (European Commission, 2019, p. 82).

With universal medical insurance covering 100% of the population, private insurance is not very popular, with only 6% of the population using it. However, this proportion is increasing due to faster access to private than public services. For the most part, private insurance is covered by employers.

Sweden has the third highest health care expenditure in Europe. Swedes spend 11% of their GDP, including 18.7% of their national budget, on health care. Per capita, this amounts to \$5,699 annually. Public spending accounts for 84% of total health care spending. The remaining expenditure consists of 15% private out-of-pocket payments and 1% private medical insurance (OECD/European Observatory on Health Systems and Policies, 2019, pp. 16–17). The average health care expenditure is less than 2% of the household budget (Borg and Sixten, 2019, p. 30).

The Swedish healthcare system is considered to be one of the best in the world in terms of organization. Despite high costs, efforts to minimize hospital treatment in favor of primary care are appreciated.

The high scores on health outcomes of the health system, however, do not seem to be appreciated by the residents themselves, who are moderately satisfied with their system. Only 34% say they are satisfied with its design, 30% are neither satisfied nor dissatisfied, and another 34% would like to see a change (IPSOS, 2020).

### 3.6 *Poland*

The main payer in the Polish healthcare system is the National Health Fund, financed partly by health contributions and partly by a dedicated budget subsidy.

In Poland, 91% of the population is covered by mandatory health insurance, and most of the uninsured are those living abroad but registered as residents in the country. The genuinely uninsured make up a negligible proportion and are mainly those employed under casual or atypical employment contracts and

informally employed (OECD and European Observatory on Health Systems and Policies, 2019).

Of the countries analyzed, Poland is by far the poorest, which is reflected in the underfunding of the healthcare system. Three basic public sources of funding can be distinguished:

1. health contribution,
2. specific budgetary subsidy,
3. expenditures of local governments.

Only persons paying the contribution are covered by insurance. The health insurance contribution amounts to 9% of the salary (contribution base) (Pietryka, 2018, pp. 233–235), and it accounted for 57.6% of the total revenue of the healthcare system in 2017 (Statistics Poland, 2019, p. 114).

Despite the constant increase in spending on the health system, Poland spends very little on health compared to countries with a similar level of development, only 6.5% of GDP, in which the share of public spending is about 70% (4.4% of GDP) (Tambor, 2018). The share of health care financing in total budget expenditure is well below the European average and accounts for only 10.9%. In per capita terms, the amounts look even worse, as they amount to only \$1,958 per citizen per year (World Bank, 2020a, 2020b).

In overall spending, the National Health Insurance Fund functions as the main payer, accounting for 85% of total public spending on health in 2018. The central government budget financed 11% of expenditures, and local and regional authorities (LRAs) financed 4%. Among the LRAs, cities with county rights spent the most, as they covered almost 1/3 of the total health expenditures at the local and regional government level (Statistics Poland, 2019, p. 119).

The Polish healthcare system is considered moderately effective. In recent years, however, improvements have been noticeable and the current direction of development seems to be increasing the effectiveness of the system, although primarily in organizational and economic terms. This is mainly due to the progressing digitalization; however, much still remains to be done in this area as well.

Among the problems facing the Polish healthcare system, the Polish Supreme Chamber of Control mentions the following:

- lack of a target vision for the system and a health policy strategy,
- uneven distribution of medical entities, inadequate to the health needs of the population,
- limited coordination of activities between particular participants of the healthcare system,
- lack of an adequate number of staff,
- decapitalization of assets, failure to meet current standards for buildings and equipment (NIK, 2019, pp. 24–140).

The issues of underfunding of the healthcare system and lack of adequate staff are widely recognized as the most important of these.

Poland is one of the countries whose inhabitants are among the most dissatisfied with their healthcare system. Only 13% are satisfied with its current shape, 13% are neither satisfied nor dissatisfied, and as many as 74% are dissatisfied (IPSOS, 2020).

#### 4 Comparative Analysis of Healthcare Systems of Selected Countries

The comprehensive analysis of healthcare systems in six developed countries selected in this chapter is the basis for comparing and contrasting them, which allows conclusions to be drawn on the effectiveness of individual systems and solutions applied in them.

##### 4.1 *Previous Comparative Analyses*

Before comparing the countries, it is worth starting with a presentation of existing quantitative summaries classifying healthcare systems and their effectiveness. Five most significant rankings developed by leading institutions have been selected as presented in Table 4.3.

Research on the efficiency and effectiveness of healthcare systems was pioneered by the World Health Organization, which launched a global discussion in this area with the publication of its ranking of systems in 2000 (WHO, 2000). It analyzed 191 countries and ranked them according to eight indicators.

TABLE 4.3 Rankings of healthcare systems and their effectiveness

Source	Year	USA	United Kingdom	Singapore	Germany	Sweden	Poland	Number of countries included in the ranking
The Economist	2014	33	23	2	19	10	54	166
Bloomberg	2018	54	35	2	45	22	24	56
EHCI	2018	n/a	16	n/a	12	8	32	35
WHO	2000	37	18	6	25	23	50	191
The Commonwealth Fund	2017	11	1	n/a	8	6	n/a	11

SOURCE: AUTHOR'S ELABORATION

Since 2005, a Swedish think-tank, the Health Consumer Powerhouse, has been publishing its own ranking as a supplement to existing evaluations, with the first edition analyzing health systems in 12 major European economies, expanded to 34 in the 2018 edition (Björnberg & Phang, 2019). The ranking itself (coupled with a comprehensive report discussing its findings), is meant to distinguish itself from others in that it takes a different perspective – it tries to rank countries by the user-friendliness of the system, and analyzes more outcome indicators than any other of the selections discussed here (Health Consumer Powerhouse, 2005).

The institutions that analyze country performance also include two leading publications – The Economist and Bloomberg. The analytical department of the first one – The Economist Intelligence Unit (2014) took a look at healthcare systems in 166 countries, dividing them into six tiers. Countries were ranked in terms of population health outcomes, which consisted of indicators including DALYS (disability-adjusted life years), HALE (health-adjusted life expectancy), life expectancy at age 60, and adult mortality, composed in such a way that the scores range from 0 to 100, where a higher score indicates better health outcomes. The countries were also ranked by their per capita health spending and the cost per outcome point.

In its ranking, Bloomberg chose to consider only countries where life expectancy exceeds 70 years, GDP per capita is greater than \$5,000, and population exceeds 5 million. There were 56 such countries. The design of the ranking itself was much simpler than the others analyzed, because it only took into account life expectancy at birth and the share of health spending in GDP (Miller & Lu, 2018). It is this oversimplification that is the biggest drawback of the Health Care Efficiency Index. Life expectancy is influenced by many other factors in addition to health system expenditures, and without taking them into account, we really still know little about the actual efficiency of the systems compared in the ranking.

The last of the selected rankings is the one developed by The Commonwealth Fund. Prepared by the American foundation in 2017, the analysis covers only 11 high-income countries (Schneider et al., 2017) and its goal is to present the best global solutions in order to find the optimal one for the US. Its results differ significantly from other rankings mentioned. The Commonwealth Fund considers quality, accessibility, value for money and equity of health care as the most important criteria. These criteria are defined by the sets of indicators chosen to determine them. With its emphasis on accessibility and per capita spending, the US was ranked just last, despite its above-average performance in health prevention, patient-centered care and innovation. The United Kingdom came in first, while performing worse in many indicators.

These examples of rankings, all produced by reputable organizations and institutions, and the differences in the performance of health systems from different countries, show how difficult it is to compare them with each other. Due to the lack of accepted standards in this area, methodological assumptions of the authors have a very high impact on the final results for individual countries. This is also indicated by the editors of *The Economist* (2014) in their commentary on The Commonwealth Fund's report. The above issues must be kept in mind both when trying to compare countries and when using and interpreting existing rankings.

The rankings that come closest to each other in terms of country performance are certainly those of the WHO (2000) and The Economist Intelligence Unit (2014). The rankings that differ most from the others are those of Bloomberg (Miller & Wei, 2018) and EHCI (Björnberg & Phang, 2018), due to the uniqueness of the criteria adopted.

The US scored best in the WHO ranking, in which it was recognized for high innovation of the system and good strictly medical effects (in this case they do not translate into population health). It fared the worst in The Commonwealth ranking, which, as *The Economist* (2014) points out, is partly the result of a very unfavorable selection of indicators for the US. The main reason for the worse performance in the rankings than the economic position and size of inputs would indicate is the extreme disproportionality of inputs to medical outcomes. This was most evident in the Bloomberg ranking, in which the US ranked third from last.

The UK ranked first in The Commonwealth Fund's ranking, which was meticulously noted by British journals (Duncan & Jowit, 2018). In other rankings, however, the UK performs worse. Just like the United States, the country scored worst in the Bloomberg ranking, allowing itself to be overtaken by 60% of the analyzed countries. It did not do much better in the EHCI ranking, where it was rated very low for the accessibility of the healthcare system, understood as waiting time for treatment.

Singapore, although included in only three of the analyzed rankings, took one of the highest positions in all of them. One of the world's longest life expectancies combined with low spending on health care could not have produced a different result. In *The Economist's* ranking, in which Singapore ranked second, the Lion City achieved the largest positive discrepancy between health outcomes and inputs.

Germany, like the US and the UK, scored the worst in the Bloomberg ranking, coming in at number 45. Relatively speaking, it ranked highest in the EHCI ranking, which recognized a strong emphasis on the patient work system and access to information, short waiting times in most cases analyzed, and good treatment outcomes.

Sweden ranked first or second in all of the rankings among the six countries analyzed. Sweden ranked highest in the EHCI, gaining approval for most indicators. Sweden is the only country in the EHCI to score maximum points in the accessibility of health care services category. In the Bloomberg ranking, Sweden is ranked 22nd, and in *The Economist* it is in the top 10.

Poland was by far the worst performer in all the rankings except Bloomberg, which placed it just two positions behind Sweden, thanks to its decent health outcomes for low investment. Poland was ranked fourth from last in the EHCI, ahead of only Albania, Romania, and Hungary. The availability of services for patients was rated lowest, but cardiological care and its effects were distinguished.

#### 4.2 *Objectives and Methodology of Efficiency Analysis: Sources of Inefficiency*

The goal of measuring, reporting, and comparing health care outcomes is to achieve the triple aim of health care:

- improve population health,
- increase the quality of individual care,
- reduce costs per person (Czerska, Trojanowska, & Korpak, 2019, p. 206).

These goals were proposed by Berwick, Nolan, and Whittington (2008) for the US and gained rapid popularity, and are nowadays also expanded to include a fourth goal: reducing staff burnout (Bodenheimer & Sinsky, 2014). Achieving the so-called Quadruple Aim is not easy and requires a highly effective organization of the healthcare system (Sikka, Morath, & Leape, 2015, p. 608).

A study published in 2009 analyzing available methods for measuring performance in health care identified 265 different indicators used in all kinds of peer-reviewed texts in the US alone (Hussey et al., 2009, pp. 789–790). From the methodological side, two basic types of comparisons can be distinguished:

- economic evaluation: consists of comparing individual components of the healthcare system in terms of their costs and benefits,
- benchmarking: compares individual health care service providers (countries, institutions) with regional or global best practices.

Based on the above methods, Section 4.4 seeks to compare the developed countries discussed in this chapter, indicating the best solutions and directions in which the healthcare systems should be reformed.

However, before comparing healthcare systems looking for sources of efficiency, it is worth considering the sources of inefficiency themselves. The OECD (2017) identifies three categories of these:

- resource-wasting clinical care,
- operational waste,
- managerial waste.



Resource-wasting clinical care refers to patients who do not receive appropriate treatment. This includes both preventable medical events resulting from errors, suboptimal decisions, and organizational factors, as well as inefficient and inappropriate low-value care caused primarily by poor staff motivation. Resource-wasting clinical care also includes unnecessary duplication of services.

Operational waste occurs when medical care could be delivered with fewer resources within the system while maintaining benefits. Examples include purchasing resources at higher prices than can be obtained, or using more expensive resources without additional patient benefit. Also falling into this category are unused resources. Operational waste most often involves individuals at managerial levels and reflects poor organization and poor coordination of processes in the healthcare system.

Managerial waste includes losses that are not directly related to patient care and take place in the process of administration and management of the healthcare system. It involves administrative waste (e.g., inefficient use of human resources in administration, excessive bureaucracy) and misuse of resources through fraud, abuse, and corruption (Expert Group on Health System Performance Assessment, 2019, p. 11).

All of the above-discussed examples of inefficiencies in the health system contribute to why the cost of maintaining it is so high. The lack of optimization in each of the areas also contributes to further increases.

### 4.3 *Determinants of Efficiency*

The healthcare systems analyzed in this chapter are extremely diverse. They differ in their inputs, organization, and outcomes. However, there is no one simple and universal solution (Helgesson & Winberg, 2009; Keller, 2017), which would allow an effective system to be constructed under any conditions, eliminating the identified sources of inefficiency. However, it is possible, on the basis of the extensive analysis made, to indicate the directions in which country-specific solutions should be sought, as well as the factors that should be taken into account when formulating such recommendations.

The factors affecting the efficiency of the healthcare system can be divided into three categories:

- input,
- political-institutional,
- cultural and social.

They are discussed in detail in the following subsections.

#### 4.3.1 Input Factors

Input factors are the most obvious category. Research clearly shows a clear positive relationship between health care inputs and outcomes such as life expectancy or infant survival. The relationship is evident around the world, regardless of the level of economic development, ranging from South Africa (Bein et al., 2017), through various developed countries, and even for individual health programs in the United Kingdom (Martin, Rice, & Smith, 2009, p. 46). However, the role of inputs alone should not be overstated. A meta-regression study published in 2017, using 65 studies published between 1969 and 2014 in this area, indicates that other factors, such as income, demographic structure, and lifestyle choices of the population, for example, also play a large role (and collectively possibly even a larger role). These were included here under the category of cultural and social factors. The study also argues that higher expenditures have a much greater effect on decreasing infant mortality than on life expectancy (Gallet & Doucouliagos, 2017), which is especially important to consider when making recommendations for developed countries, where additional expenditures might not produce the desired effect and scale.

#### 4.3.2 Political-Institutional Factors

Arguably, the second category should include political and institutional factors together. It is particularly important to combine them, because despite a certain institutional resistance, which is the effect of change-resistant institutional mechanisms and habits of people creating an institution, the latter directly result from the former. As research confirms, the policies pursued by the ruling party have a direct impact on the performance of the healthcare system. Policies aimed at leveling the playing field and redistributing income fare best in this comparison in terms of health outcomes, such as infant survival, and liberal policies fare worst (Navarro et al., 2006). Also important in this context is the evidence of a positive relationship between public and private sector efficiency and the impact of government capacity and organizational effectiveness on health system performance. This is influenced by factors such as the type of patient who goes to the private sector, the level of education of the health workforce, and the regulation and organization of the health system shaped by the development of the public sector (Morgan, Ensor, & Waters, 2016).

#### 4.3.3 Cultural and Social Factors

Cultural and social factors also have a significant influence on the effectiveness of the healthcare system, although this influence may not be as obvious as the amount of money spent or the political decisions and efficiency of institutions.

Cultural and social factors largely determine political and organizational behavior, as well as the propensity to support the allocation of public resources to healthcare. Perceptions of healthcare systems and satisfaction with them, as well as perceptions of corruption, also depend on cultural and social factors. They also influence the extent to which resources are wasted and even public perceptions of waste. For example, in the UK, Conservative and UKIP voters are 20% more likely, relative to the Liberal Democrats, to say that the NHS wastes money (Gershlick, Charlesworth, & Taylor, 2015).

#### 4.4 *Comparison of Healthcare Systems in the Countries Analyzed*

Among the analyzed countries, the US has the highest share of health expenditures in GDP (17.1% of GDP in 2017), surpassing second-ranked Germany by more than 50% (6.9 p.p.). Sweden ranks next, just behind Germany, with spending at 11% of GDP. The UK spent 9.6% in 2017. Less was spent by Poland (6.5% of GDP) and Singapore, which, with 4.4% of GDP, is one of the lowest spenders among developed countries.

The US, despite a theoretically private healthcare system, also has the largest share of health spending in total budget expenditures among developed countries. Germany is again in second place, with the UK and Sweden spending almost the same proportion of their budgets. In this category, however, it is not Singapore that is the least spender, as Poland spends as much as 1.6 p.p. less than it.

Satisfaction with medical care is a commonly used indicator in assessing the quality of treatment, and thus indirectly also makes its way into rankings of healthcare systems. Of the six analyzed in this respect, Singapore was the best, with 60% of its residents satisfied with its healthcare system. The worst performer in this respect was Poland, where almost three quarters of the population were dissatisfied with the national health system. Surprisingly low satisfaction scores were also achieved by Germany and Sweden. This can only be explained by cultural factors determining the level of patient expectations, which are much higher in Poland, Sweden, and Germany.

#### 4.5 *Conclusions and Recommendations*

Taking into account the possible influence of the above-mentioned factors and based on the proven solutions from the analyzed developed countries, a universal set of recommendations is proposed that should be taken into account in the design and development of healthcare systems. Each of the proposed solutions will bring benefits to the system, but only when implemented together can they give the expected results. Relevant recommendations are presented in the following 4 subsections.

#### 4.5.1 Data and Analytics

Healthcare systems provide huge amounts of data, most of which is not managed at all (Raghupathi & Raghupathi, 2014). The use of big data in the US raises the possibility of reducing public spending on health care by 8% (through operational efficiencies) and for private insurers to increase operating margins by up to 60% (Manyika et al., 2011, p. 2). Through predictive models, it also provides opportunities to improve countries' health outcomes. Sweden is a good example in the data management domain (Chipman, 2019, p. 5).

Data and analytics should also be used in revamping governance structures, which are suggested in the next section. A systematic and integrated evaluation of the different sectors and a study of their performance will allow a better understanding of the processes taking place and thus make it possible to redesign them more effectively.

#### 4.5.2 Reorganizing Management Structures

In order to stop further cost increases, a reorganization of the management structures of healthcare systems is necessary in many respects. The aim of such a reform would be to decentralize the system towards the Swedish model, where much of the decision-making has been transferred to local government. In Sweden, this translated into a better, more adequate and tailored spending of available resources. In order to avoid creating differences in access to medical care in particular regions, it would also be necessary, following the example of the latest Swedish solutions, to introduce additional subsidies for less wealthy and rural regions. In this area, priorities should also include a reduction in the number of hospital admissions in favor of better primary care, which, according to numerous sources, would contribute to reducing the costs of the healthcare system.

#### 4.5.3 Coordinated Care

As with the management structure, the treatment process itself needs to change in most countries. Chronic diseases account for an increasing share of all diseases worldwide (Institute for Health Metrics and Evaluation, 2017) – this generates costs and forces the search for new solutions. The direction that seems to be inevitable is coordinated care (Battersby, 2005, p. 662), which in its ideal form – at the sixth level – provides the patient with treatment and ensures an excellent flow of information between the physicians treating the patient. Although its implementation initially requires additional expenditures, in an amount that is difficult to estimate, its translation into health outcomes is expected to compensate for this and, in the long run, also bring savings to the system (Schrijvers, 2017, pp. 27–40). It is important to keep in

mind that this has not always been the case when trying to implement coordinated care. In some cases, neither cost reductions nor improved outcomes or even satisfaction have followed.

The most important non-financial effects of implementing coordinated care include:

- the possibility of greater physician specialization, due to better case allocation by the coordinator,
- better use of human resources (doctors and nurses), by reducing the number of medical consultations in favor of nursing whenever possible,
- patient involvement in the treatment process, through direct and continuous communication between the patient and the coordinator (Consensus Health, 2019, p. 4).

#### 4.5.4 Co-payments for Medical Services

Co-payments in medical care are a debatable issue in terms of recommendations for healthcare systems, but their introduction is believed to be necessary. However, it is important to properly adjust this solution to the conditions in the country concerned. Singapore shows how to do this effectively and fairly, without losing the satisfaction of patients. When implementing such a solution, it is necessary to take into account the possibilities for individual financing of services, so that no one is excluded from access to medical services.

Comprehensive implementation of the presented solutions would arguably be of great help to developed countries in coping with the problem of high and growing costs of healthcare, using the best of the systems presented in this chapter.

In relation to the theses put forward in this article, it was not possible to prove the universal impact of competition on the effectiveness of the healthcare system. Although the solutions used in Singapore contribute to system efficiency, they are not replicable in other analyzed countries due to significant differences in area and population.

Developing countries should also draw extensively on the presented solutions, but always bearing in mind that the changes should be nuanced to the extent that they fit the culture and institutional order of the country concerned.

## References

- Barros, P. P. et al. (2016). Competition among health care providers: helpful or harmful? *European Journal of Health Economics*, 17(3), 229–233. doi:10.1007/s10198-015-0736-3.

- Basu, S. et al. (2012). Comparative performance of private and public healthcare systems in low- and middle-income countries: A systematic review. *PLoS Medicine*, 9(6), doi: 10.1371/journal.pmed.1001244.
- Battersby, M. W. (2005). Health reform through coordinated care: SA HealthPlus. *British Medical Journal*, 330(7492), 662–665. doi: 10.1136/bmj.330.7492.662.
- Bein, M. A. et al. (2017). Healthcare spending and health outcomes: Evidence from selected East African countries. *African Health Sciences*, 17(1), 247–254. doi: 10.4314/ahs.v17i1.30.
- Berwick, D. M., Nolan, T. W., & Whittington, J. (2008). The triple aim: Care, health, and cost. *Health Affairs*, 27(3), 759–769. doi: 10.1377/hlthaff.27.3.759.
- Beveridge, W. (1942). *Social insurance and allied services. Report by Sir William Beveridge*. Her Majesty's Stationery Office.
- Białynicki-Birula, P. (2010). Wielowymiarowe porównania systemów zdrowotnych w krajach OECD w kontekście realizowanych modeli ochrony zdrowia. *Prace Naukowe UE we Wrocławiu, PN Finanse Publiczne* 112, 1–15.
- Björnberg, A., & Phang, A. Y. (2019). *Euro Health Consumer Index 2018 Report, Euro Health Consumer Index*.
- Bodenheimer, T., & Sinsky, C. (2014). From Triple to Quadruple Aim: Care of the Patient. *Annals of Family Medicine*, 12(6), 573–576. doi: 10.1370/afm.1713.Center.
- Borg, A. H., & Sixten, G. (2019). *Can people afford to pay for health care? New evidence on financial protection in Sweden*. World Health Organization.
- Chipman, A. (2019). *Value-based healthcare in Sweden. Reaching the next level*. The Economist Intelligence Unit. <https://impact.economist.com/perspectives/VBHC Sweden>.
- Chung, M. (2017) *Health Care Reform: Learning from other major health care systems*. <https://pphr.princeton.edu/2017/12/02/unhealthy-health-care-a-cursory-overview-of-major-health-care-systems/>.
- Consensus Health (2019). *Coordinated Care: Key to Successful Outcomes*. Marlton. <https://www.continuumhealth.net/coordinated-care-key-successful-outcomes/>.
- Cutler, D. (2018) *Reducing Health Care Costs: Decreasing Administrative Spending* [Testimony for US Senate Committee on Health, Education, Labor and Pensions]. <https://www.help.senate.gov/imo/media/doc/Cutler.pdf>.
- Cutler, D., Wikler, E., & Basch, P. (2012). Reducing Administrative Costs and Improving the Health Care System. *New England Journal of Medicine*, 367(20), 1875–1878. doi: 10.1056/NEJMp1209711.
- Czerska, I., Trojanowska, A., & Korpak, T. (2019). *Przyszłość opieki zdrowotnej w Polsce – nowe horyzonty*. E-Wydawnictwo. *Prawnicza i Ekonomiczna Biblioteka Cyfrowa. Wydział Prawa, Administracji i Ekonomii Uniwersytetu Wrocławskiego*, 153, 197–214. doi: 10.34616/23.19.120.

- Duncan, P., & Jowit, J. (2018). Is the NHS the world's best healthcare system? *The Guardian*. Retrieved September 18, 2020, from <https://www.theguardian.com/society/2018/jul/02/is-the-nhs-the-worlds-best-healthcare-system>.
- Esping-Andersen, G. (1990). *The Three Worlds of Welfare Capitalism*. Polity Press.
- European Commission. (2019). *State of Health in the EU. Companion Report 2019*. Publications Office of the European Union. doi: 10.2875/71887.
- Expert Group on Health System Performance Assessment (2019). *Tools and methodologies to assess the efficiency of health care services in Europe*. Publications Office of the European Union. doi: 10.2875/77000.
- Frączkiewicz-Wronka, A. (2009). *Zarządzanie publiczne w teorii i praktyce ochrony zdrowia*. Wolters Kluwer Polska.
- Gallet, C. A., & Doucouliagos, H. (2017). The impact of healthcare spending on health outcomes: A meta-regression analysis. *Social Science and Medicine*, 179, 9–17. doi: 10.1016/j.socscimed.2017.02.024.
- Gershlick, B., Charlesworth, A., & Taylor, E. (2015). *Public attitudes to the NHS: An analysis of responses to questions in the British Social Attitudes Survey*. The Health Foundation. <http://www.health.org.uk/sites/default/files/PublicAttitudesToTheNHS.pdf>.
- Gliklich, R., Dreyer, N., & Leavy, M. (2014). *Registries for evaluating patient outcomes: A user's guide: 3rd edition*. Agency for Healthcare Research and Quality. <https://effectivehealthcare.ahrq.gov/products/registries-guide-3rd-edition/research>.
- Grosios, K., Gahan, P. B., & Burbidge, J. (2010). Overview of healthcare in the UK. *EPMA Journal*, 1(4), 529–534. doi: 10.1007/s13167-010-0050-1.
- Health Consumer Powerhouse (2005). 2005 *EuroHealth Consumer Index, Health Consumer Powerhouse*.
- Helgesson, C.-F., & Winberg, H. (2009). Debate on future healthcare must go beyond easy solutions and answers. In H. Winberg, J. Rognes, & C.-F. Helgesson (Eds.). *Leading Health Care – Organizing healthcare for greater value* (pp. 151–155). Stockholm School of Economics.
- Hussey, P. S. et al. (2009). A systematic review of health care efficiency measures: Health care efficiency. *Health Services Research*, 44(3), 784–805. doi: 10.1111/j.1475-6773.2008.00942.x.
- Institute for Health Metrics and Evaluation (2017). Global Burden of Disease Study 2017. *The Lancet*, 2017(Gbd), 1–7.
- IPSOS. (2020). Percentage of respondents worldwide who were satisfied with their country's national health system as of 2019, by country. *Statista*. Retrieved August 27, 2020, from <https://www.statista.com/statistics/1109036/satisfaction-health-system-worldwide-by-country/>.
- James, C. et al. (2019). Decentralisation in the health sector and responsibilities across levels of government: Impact on spending decisions and the budget. *OECD Journal on Budgeting*, 19(3). doi: 10.1787/c2c2058c-en.



- Keller, R. (2017). *Health Care: A Universal Problem Without a Universal Solution*, Stratfor. Retrieved September 18, 2020 from <https://worldview.stratfor.com/article/health-care-universal-problem-without-universal-solution>.
- Kumar, S., Ghildayal, N. S., & Shah, R. N. (2011). Examining quality and efficiency of the U.S. healthcare system. *Int J Health Care Qual Assur*, 24(5), 366–388. doi: 10.1108/0952686111139197.
- Łagowski, P. (2012). Wybrane modele finansowania systemu opieki zdrowotnej. *Studenckie Prace Prawnicze, Administratywistyczne i Ekonomiczne*, 12, 81–94.
- Lewandowski, R. (2010). Modele systemów opieki zdrowotnej na świecie. In M. Kautsch, (Ed.) *Zarządzanie w opiece zdrowotnej: Nowe wyzwania* (pp. 58–66). Wolters Kluwer Polska.
- Libura, M. et al. (2018). *Finansowanie i organizacja systemu ochrony zdrowia w oczach pacjentów*. Fundacja MY Pacjenci. <https://mypacjenci.org/wp-content/uploads/2018/08/Finansowanie-i-organizacja-systemu-ochrony-zdrowia-w-oczach-pacjentw.pdf>.
- Lim, J. (2017). Sustainable Health Care Financing: The Singapore experience. *Global Policy*, 8(March), 103–109. doi: 10.1111/1758-5899.12247.
- Manyika, J. et al. (2011). *Big data: The next frontier for innovation, competition and productivity*. McKinsey Global Institute. <https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/big-data-the-next-frontier-for-innovation>.
- Martin, S., Rice, N., & Smith, P. (2009). *The link between health care spending and health outcomes for the new English primary care trusts*. The Health Foundation.
- Miller, L. J., & Wei, L. (2018). *These are the economies with the most (and least) efficient health care*. Bloomberg, Retrieved August, 22, 2020, from <https://www.bloomberg.com/news/articles/2018-09-19/u-s-near-bottom-of-health-index-hong-kong-and-singapore-at-top>.
- Moran, M. (2000). Understanding the Welfare State: The Case of Health Care. *The British Journal of Politics and International Relations*, 2(2), 135–160. doi: 10.1111/1467-856x.00031.
- Morgan, R., Ensor, T., & Waters, H. (2016). Performance of private sector health care: implications for universal health coverage. *Lancet*, 388(10044), 606–612. doi: 10.1016/S0140-6736(16)00343-3.
- Navarro, V. et al. (2006). Politics and health outcomes. *Lancet*, 368(9540), 1033–1037. doi: 10.1016/S0140-6736(06)69341-0.
- OECD/European Observatory on Health Systems and Policies. (2019). Sweden: Country Health Profile 2019, State of Health in the EU. OECD Publishing. <https://doi.org/10.1787/2dcb7ca6-en>.
- OECD. (2017). *Tackling Wasteful Spending on Health. Highlights. Tackling Wasteful Spending on Health*. OECD Publishing. doi: 10.1787/9789264266414-en.



- OECD and European Observatory on Health Systems and Policies. (2019). State of Health in the EU. Polska: Profil systemu ochrony zdrowia 2019. OECD Publishing. [https://ec.europa.eu/health/sites/default/files/state/docs/2019\\_chp\\_poland\\_polish.pdf](https://ec.europa.eu/health/sites/default/files/state/docs/2019_chp_poland_polish.pdf).
- Owoc, A. et al. (2009). System ochrony zdrowia w Stanach Zjednoczonych. *Probl Hig Epidemiol*, 90(3), 403–406.
- Papanicolas, I. et al. (2019). Performance of UK National Health Service compared with other high income countries: Observational study, *The BMJ*, 367, 1–12. doi: 10.1136/bmj.l6326.
- Pietryka, E. (2018). Finansowanie systemu opieki zdrowotnej w Polsce w kontekście wprowadzenia systemu sieci szpitali. *Journal of Management and Finance*, 16(3/1), 229–244.
- Powell, T. (2020). The structure of the NHS in England. Briefing paper CPB 07206, doi: <https://researchbriefings.files.parliament.uk/documents/CBP-7206/CBP-7206.pdf>.
- Raghupathi, W., & Raghupathi, V. (2014). Big data analytics in healthcare: promise and potential, *Health Information Science and Systems*, 2(3), 1–10. doi:10.1186/2047-2501-2-3.
- Ramesh, M., & Bali, A. S. (2019). The remarkable healthcare performance in Singapore. In M. E. Compton & P. T. Hart, (Eds.) *Great policy successes: Or, a tale about why it's amazing that governments get so little credit for their many everyday and extraordinary achievements as told by sympathetic observers who seek to create space for a less relentlessly negative view of our pivotal public institutions* (pp. 42–62) Oxford University Press. doi: 10.1093/oso/9780198843719.003.0003.
- Saltman, R. B., & Otter, C. von (1992). Planned markets and public competition. Strategic reform in Northern European health systems. Open University Press. <https://doi.org/10.1177/000169939303600205>.
- Schneider E. C., Sarnak D. O., Squires D., Shah A., Doty, M. M. (2017). *Mirror, Mirror 2017: International Comparison Reflects Flaws and Opportunities for Better U.S. Health Care*. The Commonwealth Fund.
- Schrijvers, G. (2017). *Opieka koordynowana. Lepiej i taniej*. Narodowy Fundusz Zdrowia.
- Sikka, R., Morath, J. M., & Leape, L. (2015). The quadruple aim: Care, health, cost and meaning in work, *BMJ Quality and Safety*, 24(10), 608–610. doi: 10.1136/bmjqs-2015-004160.
- Statista (2019). *Pharmaceutical spending per capita in selected countries as of 2018*. Retrieved August 23, 2020, from <https://www.statista.com/statistics/266141/pharmaceutical-spending-per-capita-in-selected-countries/>.
- Statistics Poland (2019) *Zdrowie i ochrona zdrowia w 2018 r.* Retrieved March 11, 2022, from <https://stat.gov.pl/obszary-tematyczne/zdrowie/zdrowie/zdrowie-i-ochrona-zdrowia-w-2018-roku,1,9.html>.
- Suchecka, J. (2010). *Ekonomia zdrowia i opieki zdrowotnej*. Wolters Kluwer Polska.

- Tambor, M. (2018). *Ile i z jakich źródeł wydajemy na zdrowie w Polsce?* Instytut Zdrowia Publicznego Wydziału Nauk o Zdrowiu Collegium Medicum Uniwersytetu Jagiellońskiego. Retrieved September 18, 2020, from <https://izp.wnz.cm.uj.edu.pl/pl/blog/ile-i-z-jakich-zrodel-wydajemy-na-zdrowie-w-polsce/#>.
- The Economist (2014). *How to compare health-care systems*. Retrieved September 13, 2020, from <https://www.economist.com/the-economist-explains/2014/06/29/how-to-compare-health-care-systems>.
- The Economist Intelligence Unit (2014). *Health outcomes and cost: A 166-country comparison*, The Economist. Retrieved March 11, 2022, from <http://stateofreform.com/wp-content/uploads/2015/11/Healthcare-outcomes-index-2014.pdf>.
- Tikkanen, R. et al. (2020a). *International health care system profiles: Germany*. The Commonwealth Fund. Retrieved August 24, 2020, from <https://www.commonwealthfund.org/international-health-policy-center/countries/germany>.
- Tikkanen, R. et al. (2020b). *International health care system profiles: Sweden*. The Commonwealth Fund. Retrieved September 10, 2020, from <https://www.commonwealthfund.org/international-health-policy-center/countries/sweden>.
- Tikkanen, R., Abrams, M. K. (2020). *U.S. health care from a global perspective, 2019: Higher spending, worse outcomes?* The Commonwealth Fund. Retrieved September 9, 2020, from <https://www.commonwealthfund.org/publications/issue-briefs/2020/jan/us-health-care-global-perspective-2019>.
- Tunstall, L. (2016). *The UK health care system*. Evidence Network. Retrieved August 18, 2020, from <https://evidencenetwork.ca/the-uk-health-care-system/>.
- WHO. (2000). *The World Health Report 2000*. World Health Organization.
- WHO. (2007). *Everybody's business. Strengthening health systems to improve health outcomes*. World Health Organization.

# Value Based Healthcare (VBHC) as a Tool for Achieving Clinical Effectiveness

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## Abstract

Clinical and cost-effectiveness in healthcare leads to action and solutions to existing problems. Change should enable patients to improve their health while also reducing the costs associated with such improvements. In order to introduce VBHC, the groundwork needs to be completed. First, a set of Key Performance Indicators (KPIs) should be developed to provide a base for making rational decisions. The significance of such a set is high, as it encompasses many factors that help determine the results to be obtained. Knowing the conditions and problems associated with the introduction of VBHC into the healthcare system as a research value, one should consider the conclusions resulting from the review of selected literature related to the concept of VBHC. Since the most important criterion adopted in this chapter is the efficiency aspect of the introduction of VBHC, the presentation of the course of reasoning combining benefits and costs, as well as the practical use of such an approach is a value-added contribution to the development of the discipline. Moreover, the chapter emphasizes the need to design KPIs as an indispensable basis for using VBHC in practice. This is a contribution to the development of the most important mainstream analysis created and used for quantitative tools.

## Keywords

healthcare system – efficiency – value based healthcare

## 1 Introduction

In recent years, the situation in healthcare has been complicated and difficult in all European countries, for all stakeholders. There are many reasons for this, such as the aging of the population, costs of advances in medical science, and the growing expectations of patients. Additionally, the situation is exacerbated

by the Covid-19 pandemic. As a result, the availability and quality of health services are worse than potentially possible. The impact of money shortage as well as waste in healthcare should be emphasized. This involves the waste of human, physical, and financial capital and ignoring unnecessary expenses.

The European Commission has emphasized the importance of cost-effectiveness and the resulting clinical effectiveness based on OECD publications:

Evidence suggests that as much as one-fifth of health spending is wasteful, and could be reduced or eliminated without undermining health system performance. With as much as 9.6% of European GDP directed to health care, reducing such spending is thus important not only for improving access to needed care, but also for ensuring health system resilience.

OECD, 2018, p. 45

According to the EU website, the value of improper treatment and wasted resources was even estimated at 34% of expenses incurred (EXPH, 2019). A problem that has been raised for years should also be mentioned, namely that of the effectiveness of treatment. Many patients do not benefit from the first drug they are offered in treatment. For example, the percentage of the patient population for whom a particular drug in a class is ineffective, on average, is following: SSRI (selective serotonin reuptake inhibitor) anti-depressants – 38%, asthma drugs – 40%, diabetes drugs – 43%, arthritis drugs – 50%, Alzheimer's drugs – 70%, cancer drugs – 75%. It turns out that one size does not fit all. Studies have linked these differences in response to the differences in genes (Spear et al., 2001). The concept of Value Based Healthcare is a way to help solve the problems of substandard effectiveness of treatment as well as waste and scarcity of all resources. This is possible because VBHC uses personalized medicine, which is based on genome-based treatment. In European countries, including Poland, there is a discussion on the possibility of just such a reform of the healthcare system.

The most important goal for health protection is to ensure the proper effectiveness of treatment and thus the health of patients. However, achieving this goal is possible only with the pursuit of economic and, above all, financial efficiency. Actually all over the world health expenditures continue to rise at an alarming rate. They outpace the growth of GDP (Park et al., 2007). It is now known that focus only on costs and volume is misguided or even leads to a dead end. Because this problem is a challenge for all decision-makers and scientists related to healthcare, a new approach is needed and healthcare systems should be reoriented. The possibility of using VBHC as a way to improve the functioning of the healthcare system becomes an objective.

## 2 Value Based Healthcare

An approach to VBHC was proposed by Porter (M. Porter & Teisberg, 2006). In his initiatory book, together with Teisberg, he presented quite a new approach to financing, organization and management in healthcare. In many subsequent articles, Porter developed his ideas and refined certain aspects of his VBHC concept, that is, measurement of improvements in health, innovation slow-down, inappropriate cost containment and micromanagement of physicians' practices. He also stressed that measuring the value of health would allow the reimbursement system to be reformed, the purpose of which is to provide bundled payments covering the full cycle of care (M. E. Porter, 2010). The World Economic Forum and the Boston Consulting Group (BCG) launched a special project devoted to the Value in Healthcare in 2016. Analyses show that four goals should be pursued:

- To develop a comprehensive understanding of the key components of value-based health systems
- To draw general lessons about the effective implementation of value-based healthcare by codifying best practice at leading healthcare institutions around the world
- To identify the potential obstacles preventing health systems from delivering better outcomes that matter to patients, and at lower cost
- To define priorities for industry stakeholders to accelerate the adoption of value-based models for delivering care (World Economic Forum, 2017, p. 6).

European Commission experts have proposed that VBHC be defined as a comprehensive concept built on 4 pillars: (1) personal value (appropriate care to achieve patients' personal goals); (2) technical value (achievement of best possible outcomes with available resources); (3) allocative value (equitable resource distribution across all patient groups); (4) social value (contribution of healthcare to social participation and connectedness) (EXPH, 2019).

In seeking to deal with the problem of growing money shortage, waste of resources, the effectiveness of treatment, the possibility of basing healthcare on the VBHC concept is important. This approach to the functioning of the healthcare system focuses on the patient and combines the interests of doctors and economists, medical workers and hospital managers. The following selected sets of issues represent the most important problems that decision-makers must solve. So, they are interested in the main causes of waste of all types of resources in healthcare. The sources of waste can be considered under the following three categories:

- (1) Reasons why patients do not receive proper treatment: duplication of tests and services; low-value care: ineffective, inappropriate, not cost-effective; avoidable adverse events;

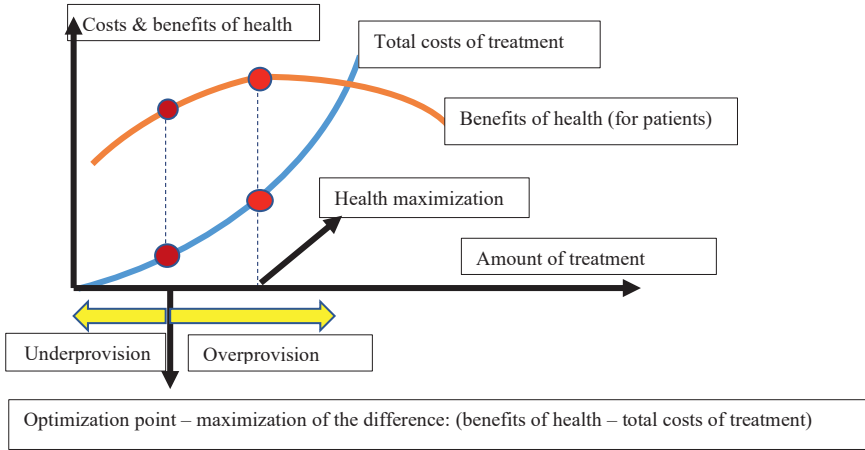


FIGURE 5.1 Relationship between the amount of treatment and the total costs of treatment and health benefits  
SOURCE: AUTHORS' ELABORATION

- (2) Benefits that could be obtained with fewer resources by eliminating: discarded inputs, e.g. purchased drugs; overpriced inputs (e.g. generic vs brand products); high-cost inputs used unnecessarily (HR, hospital care);
- (3) Resources being unnecessarily taken away from patient care due to administrative waste; fraud, abuse and corruption (OECD, 2017).

Thus, the basis for making decisions must be an appropriate analysis of the costs of health services and the resulting health improvements. Thus, it turns out that the quantity of health services must be the result of the costs and benefits of providing these services as shown in Figure 5.1.

The implementation of VBHC is another problem. Experts design the various stages of the healthcare reform towards VBHC. One of the suggestions can be found in an article in which Porter and Lee described the next steps to introduce VBHC (Porter & Lee, 2013). According to their approach, the system should consist of the following components:

- (1) Coordination units;
- (2) Measurement of health outcomes and costs;
- (3) Financing medical services: payments for medical services; value-based pricing; value-based procurement;
- (4) System coordination;
- (5) Introduction of an IT and information system.

However, one gets the impression that the quantity and order of these elements seem debatable.

It should be noted that the most important factor determining the amount of expenditures and the state of health of patients is the method of reimbursement of health care providers for costs incurred. This is because the reimbursement method is an incentive for medical staff to make decisions on treatment methods, and thus on costs incurred by the health care provider. Therefore reimbursement incentives should be designed in such a way that it is possible to achieve the best relationship between the costs incurred for treatment and its health outcomes.

Since the main goal is to improve health, the mechanism for achieving value improvement in healthcare can be represented by the following steps that the decision-maker should take:

1. Collect and share transparent, high-quality outcome data;
2. Analyze variations;
3. Identify current best practices;
4. Change behaviors;
5. Generate feedback and learning
6. Enhance value (Soderlund et al, 2012)

The proposed reform of the healthcare system based on VBHC describes a delivery model in which all providers are paid based on patient health outcomes. The benefits of such a system are achieved by the entire society and economy, and in particular by patients, providers, and payers. The benefits for all stakeholders are: (1) providers achieve economic/financial efficiency and clinical effectiveness; (2) payers control costs, reduce risk and align prices with patient outcomes; (3) patients spend less money to achieve better health; (4) the economy achieves faster economic growth and development, which improve the welfare of society; (5) society becomes healthier while reducing overall healthcare spending.

### 3 Personalized Medicine

Personalized medicine can be defined as follows: It is the use of interdisciplinary knowledge about humans, underlying the prediction of all possible disease courses and treatment prognoses, and thus achieving an improvement in health (Drummond et al., 2005). This means tailored treatment, as patients are stratified into groups based on their susceptibility to disease or their response to particular treatments. Thanks to the identification of risk factors, effective prevention is possible, and thanks to genetic identification and knowledge of the molecular pathology of a disease, it can be treated effectively.

The use of personalized medicine (PM) is a condition that seems necessary for the implementation of VBHC. While there is no universally accepted definition, the European Union Health Ministers defined it as:

A medical model using characterization of individuals' phenotypes and genotypes (e.g. molecular profiling, medical imaging, lifestyle data) for tailoring the right therapeutic strategy for the right person at the right time, and/or to determine the predisposition to disease and/or to deliver timely and targeted prevention.

European Commission, 2015

The application of PM means that the right drug and right dosage are selected based on the patient's genome. This makes it possible to avoid taking a drug that is not working or causes adverse side effects. Additionally, PM reveals the molecular predisposition of each patient to a specific disease, and this makes it possible to deliver timely and targeted prevention (European Commission, 2015). To sum up, health outcomes cannot be maximized without patient diagnosis and treatment with the use of PM.

The development of PM depends on interdisciplinary studies, of which two research areas are the most important.

The first group of problems is related to costs and cost-effectiveness questions: (1) How to calculate cost-effectiveness for personalized medicine? (2) How can precision medicine be cost-effective, maybe even more cost-effective than traditional approaches? (3) How to introduce flexibility in conventional payment systems to account for performance (outcome-based payments)?

The second group of questions is connected with innovative financing and payment systems: (1) Cost and pricing: how to calculate the price of a unique life-time dose for an inherently individualized cure? (2) How to develop new payment systems such as those that are widely used in other fields affected by typically low-probability/high impact events (e.g. loans, mortgages, securitization)? (3) How to make these systems affordable and socially acceptable? (4) How to establish the performance of an individualized treatment and how to modulate the price in relation to its outcome or effectiveness and overall value? (5) How to introduce planned flexibility? (6) The cost of "curative" initial treatments may be at the expense of payers who are not those who will see the benefit in the long-term (e.g., Alzheimer's disease) (Nursimulu et al., 2018).

### 3.1 *Economic Evaluation of Personalized Medicine*

The scarcity of resources (medical workers, money, equipment) forces us to constantly research how healthcare resources are used to eliminate any inefficiencies. When focusing on personalized medicine, one should use the tools of



economic assessment, which is a comparative analysis of alternative decisions taking into account both costs and benefits. In this case, the alternatives are treatments using genetic testing, that is, treating the patient, and traditional treatment, that is, treating the disease.

Four basic methods are used for economic evaluation. The first is CMA (cost-minimization analysis), which is used when the health outcomes are the same and the cheapest treatment option can be chosen. The second is CEA (cost-effectiveness analysis) used when the results are measured in the same units to select an alternative whose cost per unit of result is lower than the threshold adopted by the HTA agency, the Health Technology Assessment Agency (AOTMiT) in Poland. Third, there is a specific version of the CEA available, CUA (cost-utility analysis), which is used when the results differ and a common measure is needed, which is generally QALY (Quality-Adjusted Life Year). According to the CUA, the alternative is selected for which the cost of obtaining one QALY is lower than the threshold set by the HTA. The fourth one is CBA (cost-benefit analysis), which can be used when the results, due to their differentiation, can only be expressed in money. The alternative is chosen that gives the highest non-negative net present value, that is, the difference between the discounted expected benefits and costs in cash terms.

Beginning with the qualitative analysis, which provides an intellectual framework for further analysis, it is worth starting with listing the potential benefits of using personalized medicine. These include: greater certainty about the diagnosis and the course of disease; better estimation of the risk of subsequent complications and negative outcomes, which allows better management of treatment; better prediction of response to treatment and reduction of negative effects; reducing the waste of healthcare resources by treating drug-resistant patients; improving the quality and cost-effectiveness of a tailored treatment compared to traditional treatment.

It is also worth identifying the potential consequences for each type of stakeholder. For patients, the increase in their costs will be influenced by: higher drug prices and the cost of pharmacogenetic tests. On the other hand, the reduction of costs for them will be possible thanks to: reducing the likelihood of negative consequences; elimination of ineffective treatment; improving health. From the perspective of the service provider/payer, the increase in the cost of personalized treatment will be caused by: higher prices of medicines; the cost of pharmacogenetic testing (including the cost of false positives and negatives); increasing the population of patients treated with particular drugs; enhanced protection for drug and test patents; training, testing and interpretation costs. On the other hand, the reduction of costs will be possible thanks to: reducing the use of resources in healthcare after eliminating waste; skipping treatment for those who are refractory to certain treatments; increasing the

share of effective treatment; avoiding treatment with negative consequences and complications; reducing the number of medical malpractice cases. For the industry, the increase in costs will result from: higher R&D costs in the short term; regulatory costs due to a more stringent test approval process; the end of the “cult” drug business model; differentiation between the drug and test industries. On the other hand, the reduction of costs will be caused by: improvement of the decisions made and thus increased medical effectiveness; precise concentration of research programs and thus obtaining better results; early acceptance of new therapies; greater certainty in post-marketing surveillance systems; increasing the patient population for whom the drugs will be effective. From the point of view of all stakeholders and the government budget, the goal to be achieved is not to use, and thus not to pay for, methods that are ineffective.

Benefits obtained thanks to personalized medicine can also be classified as direct net benefits and indirect (social) benefits (Castonguay et al., 2012). Direct net benefits are achieved both by healthcare and by patients and their families, generally informal caregivers. The benefits achieved by healthcare include the costs incurred due to prevention and effective treatment, lower costs of this treatment, and include savings due to less frequent and shorter hospitalizations, fewer consultations with specialists and hospital emergency departments, that is, savings resulting from lower consumption of healthcare resources. On the other hand, the direct net benefits for patients are: reduced direct expenditure, primarily on drugs and medical supplies, and care, less use of long-term care, and lower travel expenses for treatment. Indirect benefits, also referred to as social benefits, are achieved by patients thanks to disease prevention and the possibility of curing them, and they are achieved by reducing morbidity and mortality. This means a reduction in presenteeism and absenteeism, which has an economic dimension as more GDP is produced, and a psychological dimension where patients and their families enjoy a higher quality of work and private life. At the population health level, these benefits mean improved quality of life, increased life expectancy, and reduced premature deaths. Indicators such as QALY and DALY (Disability-Adjusted-Life-Years), which measure the health status of a society, are also improving. From the point of view of economic analysis, two methods are used to determine the monetary value of limited mortality and morbidity, namely the human capital method, which is the most important, and additionally, the friction cost method and the willing-to-pay method can be used. The most commonly used human capital method focuses on the productivity and volume of production that successfully treated people will generate through good health. In the case of traditional treatment that leads to presenteeism of sick people and their

informal caregivers, absenteeism of these people, as well as invalidity and premature deaths, the economic and social cost is the value of lost GDP as a result of the disease. Moreover, the value of unpaid taxes and contributions, that is, reduced government budget revenues, should be taken into account, as well as the value of social benefits paid to people unable to work, that is, increased government budget expenses.

### 3.2 *Benefits of Using the Economic Assessment of Personalized Medicine*

Thanks to the economic analysis, it is possible to determine the value obtained for the money spent (value-for-money). Calculations and estimates are made in a dynamically changing environment, because, on the one hand, the expectations of patients and their families regarding the effectiveness of treatment are growing, and, on the other, the conditions of treatment are changing due to the progress in medical science and the need to change legal regulations concerning, in particular, valuation, imposed by it. In particular, it is about procedures and methods of reimbursing hospitals for costs incurred for treatment by payers. With this approach, the value of the benefits (preferably in economic or social terms) can be divided by the cost of the procedure or treatment. In order to compare the benefits and costs, as well as value-for-money, thanks to the use of personalized medicine and traditional treatment methods, it is best to plot a decision tree, a tool commonly used in medicine. This way, all possible alternatives, their monetary dimension and the probabilities of the occurrence of individual states are summarized (Blank et al., 2011).

Calculations made with the use of health economics analysis in 2014 (PMC, 2014) show that the use of chemotherapy in women with breast cancer will decrease by 34% each year thanks to the use of genetic tests. The number of strokes will decrease by 17,000 a year after the introduction of genetic testing to diagnostics (McWilliam et al., 2006). Expenditure on colon treatment will decrease by US\$ 604 million annually after the introduction of a pre-treatment genetic test (Shankaran, 2009). Such an increase in the benefits of using personalized medicine is accompanied by a reduction in the costs of using scientific and technical progress in medical science, and so the cost of sequencing the human genome in 2001 was US\$ 300,000,000, and in 2014 it was only US\$ 1,000 (PMC, 2014a).

In economic assessment, the cost-effectiveness study uses calculations showing the costs divided by the life years gained, which means that it is known how much each year of extended life costs. Of course, in severe diseases, in addition to the duration of life, its quality is important and therefore a utility and cost analysis is used, according to which costs should be converted into QALYS – quality-adjusted life years (Nojszewska, 2010).

Therefore, the cost and effectiveness level can be represented as shown in Figure 5.2 (Morris et al., 2011). In practice, improvement in clinical efficacy is most often accompanied by an increase in treatment costs. Therefore, health technology assessment agencies, including AOTMiT in Poland, introduce profitability thresholds. In most countries, including Poland, it is 3% of GDP per capita for one QALY, because QALY is the best way to assess the effectiveness of spending on medical interventions. American experts estimate the cost-effectiveness of treatment at 50–100 thousand dollars per year for one QALY, that is, for a year of “full-quality” life. This is a brutal approach, but it is due to the fact that all health systems face budgetary constraints. This situation is used by pharmaceutical companies to promote their products.

The confrontation of costs and benefits is aimed at unambiguous determination whether personalized medicine is cost-effective. The pharmacoeconomic literature shows that this is the case for all types of diseases. It is particularly important in the case of oncology, as the cost of cancer treatment is increasing worldwide. Thus, there is a confrontation between the decreasing costs of genetic tests and the increase in the costs of traditional treatment, which is an irrefutable argument when designing health policy and the valuation of medical procedures (PMC, 2014a).

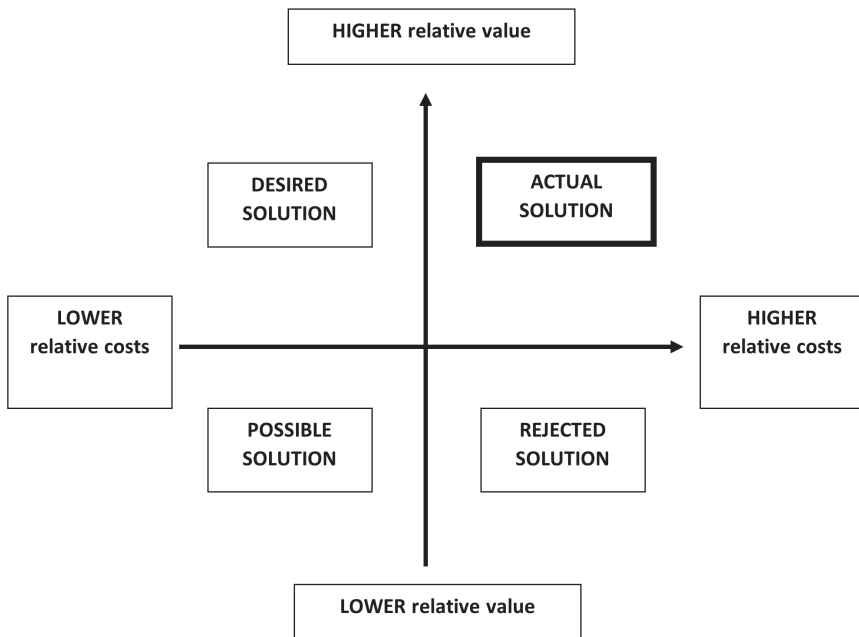


FIGURE 5.2 Economic interpretation of the use of personalized medicine in the cost-effectiveness table

SOURCE: AUTHORS' ELABORATION

#### 4 Key Performance Indicators (KPIs)

Seeking to implement VBHC based on personalized medicine, it should be emphasized that this will be possible not only due to progress in medical science, but also thanks to the introduction of appropriate incentives for the purposes of health protection, the most important of which are KPIs.

It can be said that with personalized medicine the outcome of a therapy will be known, which means that health care will cease to be an “experience good”, the quality of which can be known after it has been consumed, and will become a “search good”, the quality of which is known even before the therapy, although in an imperfect way (Nelson, 1970). Healthcare decision-makers seek to understand the economic value of both PM and the optimal pricing of all resources. One of the challenges for PM is patient adherence to treatment. Research shows that non-adherence is an important source of losses. For example, in the US healthcare sector, the losses caused by this in 2014 amounted to about 2.3% of GDP (Egan & Philipson, 2014).

The potentiality of introducing the VBHC idea based on personalized medicine depends on multi-dimensional analysis of the financing, organization and management of the healthcare system taking into account all stakeholders. Should be noted that this is not enough to gain the knowledge of the healthcare sector alone, including patients, payers and insurers. It is necessary to know at least the economic/macroeconomic and social conditions. Properly designed KPIs are the most important tool for acquiring the necessary knowledge. Thus, it can be concluded that it is not only about KPIs related to the medical effectiveness and efficiency of mainly hospitals and all providers. These types of KPIs have long been in place and their values are known and can actually be calculated. The other mentioned types of KPIs showing economic conditions, the public finance framework, social and individual behavior, and the way decisions are made by politicians, bureaucrats, individuals and the whole society are no less important. It turns out that optimization of the quantity and quality of health services is not possible without knowing all these types of measures. VBHC cannot be introduced without KPIs and results of quantitative and qualitative analyses (providing knowledge of the organization, management, financing, investing, and overall functioning of healthcare) (PMC, 2014a). The research conducted so far shows that it is necessary to create a set of the most important key performance indicators (PhRMA, 2015). Building on the knowledge gained from KPIs, it will be possible to make the necessary valuations, control the quality and quantity health services, as well as exercise strategic and operational management of all healthcare providers and the system as a whole. All of this can be done in accordance with the adopted objectives and standards (Arah et al., 2003).

The structure of KPIs necessary for health care focused on the patient and their health status should contain the following components:

- (1) Performance levels: strategic, tactical, operational;
- (2) Performance dimensions: safety, effectiveness, efficiency, timelines, equity, patient centeredness;
- (3) System components: structure, processes, outcomes (Khalifa et al., 2015).

The research on the basis of which the above has been written shows that KPIs for the healthcare system should include three levels of assessment of the functioning of service providers (strategic, tactical and operational) (Eckerson, 2009). The performance dimensions of healthcare functioning necessary for evaluation on the basis of indicators are: patient health safety, clinical effectiveness of treatment, resource efficiency, appropriate time to carry out the treatment process, focus on patient centeredness understood as improving health status and patient satisfaction, as well as equal access for all patients and all types of benefits. In addition, KPIs should assess three components of the treatment process, that is, firstly, a structure representing treatment determinants (e.g., hospital, staff, equipment, financing); secondly, processes that reflect all relationships between healthcare providers and patients during treatment; and thirdly, treatment outcome revealing its impact on the health of the individual and society (Gilbert, 2015).

It has become a goal for decision-makers and researchers alike to develop a group of strategic KPIs to monitor and improve the performance of the healthcare system and all stakeholders, especially hospitals. Such KPIs require an operational definition to be formulated, since they are in essence quantitative measures of quality (Ibrahim, 2001; Thompson & Harris, 2001; Wolfson, 1994). It should be mentioned that many hospitals have been developing KPIs for monitoring, measuring, and managing their performance. Managers strive to ensure the achievement of clinical effectiveness and economic efficiency, and also equality and quality of health services (Khalifa & Khalid, 2015). Examples of KPIs used in hospitals are as follows:

- (1) Average Hospital Stay: Evaluate the amount of time your patients are staying;
- (2) Bed Occupancy Rate: Monitor the availability of hospital beds;
- (3) Medical Equipment Utilization: Track the utilization of your equipment;
- (4) Patient Drug Cost Per Stay: Improve cost management of medications;
- (5) Treatment Costs: Calculate how much a patient costs to your facility;
- (6) Patient Room Turnover Rate: Balance the turnover with speed and quality;
- (7) Patient Follow-up Rate: Measure the care for your patients over time;
- (8) Hospital Readmission Rates: Track how many patients are coming back;
- (9) Patient Wait Time: Monitor waiting times to increase patient satisfaction;
- (10) Patient Satisfaction: Analyze patient satisfaction in detail;
- (11) Staff-to-Patient Ratio: Ensure you have enough staff to care for your patients;
- (12) Canceled/

missed appointments: Keep track of patients' appointments; (13) Patient Safety: Prevent incidents happening in your facility; (14) ER Wait Time: Identify rush hours in your emergency room; (15) Costs by Payer: Understand the type of health insurance of your patients (DATAPINE, 2021).

Researchers seek to design the most important (economic, social) classes of KPIs and all related individual indicators. To achieve this, they have to answer a number of questions that define the framework for effective functioning of health care and all stakeholders. It is imperative to know and understand all the economic and social determinants of performance frameworks for health-care, its economic efficiency, and clinical effectiveness (Arah et al., 2003).

To sum up, it is worth emphasizing that there are attempts to implement personalized medicine in the European Union member countries as a condition for the use of VBHC and that means that the creation of KPIs is of particular importance.

## 5 Discussion and Conclusions

The most important criterion adopted in this chapter is the efficiency of VBHC adoption. That is why the presentation of rationale that combines health benefits and incurred costs, as well as the practical implementation of the VBHC model of the healthcare system is a value-added contribution to the development of this interdisciplinary research. Most importantly, the chapter emphasizes the need to design all desired types of KPIs as an essential basis for the functioning of VBHC in practice. It contributes to the development of the most important kind of analysis creating and using for statistical and generally speaking quantitative tools, of course apart from quality tools such as PROMS (Patient-Reported Outcome Measures), PREMS (Patient-Reported Experience Measures) and other metrics.

Problems with clinical effectiveness and cost effectiveness/economic efficiency in European healthcare systems represent a push to take whatever measures are needed to arrive at appropriate solutions. All improvements should be designed so as to deliver the desired outcomes: they will enable patients to improve their health status and minimize the costs of this improvement. The introduction of VBHC requires many steps, so one needs to prepare the ground for this reform, which requires many time-consuming and interdisciplinary activities. The work should begin with the KPIs that will provide indicators for making rational decisions in all aspects. The significance of such a set of needed KPIs is that it represents many factors (hopefully the most important ones) that determine the results obtained.



The situation in all healthcare systems in Europe (and most likely all over the world) requires immediate changes, of which VBHC seems to be the best solution because it is based on clinical and cost-effectiveness. However, due to the complexity of the determinants of clinical effectiveness, including medical problems and their intricate correlation with economic and social conditions (e.g., public finances, financial capacity, organization and management of the healthcare system, macroeconomic situation, etc.), it reveals research limitations. The largest and the most important of these is the lack of databases, both of medical records (for clinical effectiveness) and databases for the healthcare system as a whole and for individual stakeholders (for economic and social efficiency). There are many limitations, the most important of which is the initial period of work on solutions, and above all KPIs enabling the introduction of VBHC into practice, which also poses a research challenge. Another example of research limitation is the diversity of health care and economic conditions in each country. This is a particular impediment to experience sharing between individual countries. In planning research that will enable the introduction of VBHC in the near future along with ongoing quantitative and qualitative analyses, new research questions and research limitations appear. The biggest problem and limitation facing the research that needs to be done is that only partial and selective qualitative data is available and they are collected differently from country to country. This causes problems with comparisons among countries because of the complexity of the databases and assumptions made in the research conducted in different national settings. Unfortunately, based on the experience gained so far, it can be concluded that controlled implementations of VBHC and access to homogenic cases for cross-country analysis is very rare. Everyone is aware of how important it is to know the experience of countries that have already started implementing the VBHC approach. The literature shows that differentiated value-based approaches are being introduced incrementally and at varying scope and speeds across the healthcare systems in Europe. Introducing this revolutionary reform also represents a tremendous shift in culture for all stakeholders. Healthcare is constructed differently in each country and faces different conditions, and therefore none can mechanically implement recommendations developed in other countries.

Looking at future research, it can be seen that research problems and limitations emerge as further research areas, because one has to deal with them first to be able to put VBHC into practice. However, at the current stage of all types of research, it seems that the most important research challenge is to create the right sets of KPIs that will present a comprehensive picture of both the clinical effectiveness and efficiency of economic functioning of the healthcare system. It is obvious that KPIs should cover all types of conditions affecting the quality and availability of health services.



## References

- Arah, O., Klazinga, N., Delnoij, D., ten Asbroek, A., & Custers, T. (2003). Conceptual frameworks for health systems performance: a quest for effectiveness, quality, and improvement. *International Journal for Quality in Health Care*, 15(5), 377–398. <https://doi.org/10.1093/INTQHC/MZG049>.
- Blank, P. R., Moch, H., Szucs, T. D., & Schwenkglens, M. (2011). KRAS and BRAF mutation analysis in metastatic colorectal cancer: A cost-effectiveness analysis from a Swiss perspective. *Clinical Cancer Research*, 17(19). <https://doi.org/10.1158/1078-0432.CCR-10-2267>.
- Castonguay, J., de Marcellis-Warin, N., & Mishagina, N. (2012). *Evaluating the Potential Socio-Economic Impact of Personalized Medicine*. Project Report (CIRANO). 2012RP-10.
- DATAPINE. (2021). *Healthcare Key Performance Indicators and Metrics*. <https://www.datapine.com/kpi-examples-and-templates/healthcare>.
- Drummond, M., Sculpher, M., Torrance, G., O'Brien, B., & Stoddart, G. (2005). *Methods for the economic evaluation of health care programmes*. Oxford University Press.
- Eckerson, W. (2009). Performance management strategies. *Business Intelligence Journal*, 14(1).
- Egan, M., & Philipson, T. J. (2014). Health Care Adherence and Personalized Medicine. In *NBER WORKING PAPER SERIES* (No. 20330; NBER WORKING PAPER SERIES, Issue 20330). <http://www.nber.org/papers/w20330>.
- EHPX. (2019). Defining value in 'value-based healthcare'. Report of the Expert Panel on Effective Ways of Investing in Health (EXPH), Publications Office of the European Union. <https://doi.org/10.2875/872343>.
- European Council (2015). Council conclusions on personalised medicine for patients (2015/C 421/03), [https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015XG1217\(01\)&from=FR](https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015XG1217(01)&from=FR).
- Gilbert, S. M. (2015). Revisiting structure, process, and outcome. *Cancer*, 121(3), 328–330. <https://doi.org/10.1002/CNCR.29070>.
- Ibrahim, J. (2001). Performance indicators from all perspectives. *International Journal for Quality in Health Care*, 13(6), 431–432. <https://doi.org/10.1093/INTQHC/13.6.431>.
- Khalifa, M., & Khalid, P. (2015). Developing strategic health care key performance indicators: A case study on a tertiary care hospital. *Procedia Computer Science*, 63, 459–466. <https://doi.org/10.1016/J.PROCS.2015.08.368>.
- McWilliam, A., Lutter, R., & Nardinelli, C. (2006). *Health care savings from personalizing medicine using genetic testing: the case of warfarin*. AEI-Brookings Joint Center for Regulatory Studies. <https://www.worldcat.org/title/health-care-savings-from-personalizing-medicine-using-genetic-testing-the-case-of-warfarin/oclc/86078261>.
- Morris, S., Devlin, N., & Parkin, D. (2011). *Ekonomia w ochronie zdrowia*. Wolters Kluwer Polska.

- Nelson, P. (1970). Information and consumer behavior. *Journal of Political Economy*, 78(2), 311–329. <https://doi.org/10.1086/259630>.
- Nojszewska, E. (2010). Quality-Adjusted Life Years (QALYs) jako narzędzie ekonomicznej oceny zdrowia. *Collegium of Economic Analysis Annals*, 22, 165–180. <https://ideas.repec.org/a/sgh/annals/i22y2010p165-180.html>.
- Nursimulu, A., Florin, M.-V. & IRGC. (2018). *Workshop Report: The economics of precision medicine*. <https://doi.org/10.5075/EPFL-IRGC-256776>.
- OECD. (2018). *Health at a glance: Europe 2018: State of health in the EU cycle* (Health at a Glance: Europe 2018). OECD Publishing. [https://doi.org/10.1787/health\\_glance\\_eur-2018-EN](https://doi.org/10.1787/health_glance_eur-2018-EN).
- OECD. (2017). *Tackling Wasteful Spending on health*. <http://dx.doi.org/10.1787/9789264266414-en>.
- PMC. (2014). *Personalized medicine by the numbers*. Personalized Medicine Coalition. [http://www.personalizedmedicinecoalition.org/Userfiles/PMC-Corporate/file/pmc\\_personalized\\_medicine\\_by\\_the\\_numbers.pdf](http://www.personalizedmedicinecoalition.org/Userfiles/PMC-Corporate/file/pmc_personalized_medicine_by_the_numbers.pdf).
- PMC. (2014a). *The case for personalized medicine*. Personalized Medicine Coalition. [http://personalizedmedicinecoalition.org/Resources/The\\_Case\\_for\\_Personalized\\_Medicine](http://personalizedmedicinecoalition.org/Resources/The_Case_for_Personalized_Medicine).
- PhRMA. (2015). *Value of personalized medicine*. [http://phrma-docs.phrma.org/sites/default/files/pdf/chart\\_pack-value\\_of\\_personalized\\_medicine.pdf](http://phrma-docs.phrma.org/sites/default/files/pdf/chart_pack-value_of_personalized_medicine.pdf).
- Porter, M. E. (2010). What is value in health care? *The New England Journal of Medicine* 363(26): 2477–81. <http://vbhcprize.com/wp-content/uploads/2014/03/Porter-What-is-value-in-healthcare.pdf>
- Porter, M. E., & Lee, T. (2013). The strategy that will fix health care. *Harvard Business Review*. <https://hbr.org/2013/10/the-strategy-that-will-fix-health-care>.
- Porter, M. E., & Teisberg, E. (2006). *Redefining health care: Creating value-based competition on results*. Harvard Business School Press.
- Park, M., Braun, T., Carrin, G., & Evans, D. B. (2007) Provider payments and cost-containment lessons from OECD countries. *Technical Briefs for Policy Makers*, No. 2.
- Shankaran, V. (2009). *Conference presentation at the Gastrointestinal Cancers Symposium*. <https://www.medscape.com/viewarticle/586946>.
- Soderlund, N., Lawyer, P., Larsson, S., & Kent, J. (2012). Progress toward value based health care – lessons from 12 countries. The Boston Consulting Group. <https://www.bcg.com/publications/2012/health-care-public-sector-progress-toward-value-based-health-care>.
- Spear, B., Heath-Chiozzi, M., & Huff, J. (2001). Clinical application of pharmacogenetics. *Trends in Molecular Medicine*, 7(5).
- Thompson, B., & Harris, J. (2001). Performance measures: Are we measuring what matters? *American Journal of Preventive Medicine*, 20(4), 291–293. [https://doi.org/10.1016/S0749-3797\(01\)00294-X](https://doi.org/10.1016/S0749-3797(01)00294-X).

- Wolfson, M. (1994). *Social proprioception: measurement, data and information from a population health perspective*. In R. Evans, M. Barer, & T. Marmor (Eds.), *Why are some people healthy and others not?* Routledge Boca Raton.
- World Economic Forum (2017). *Value in healthcare laying the foundation for health system transformation*. [http://www3.weforum.org/docs/WEF\\_Insight\\_Report\\_Value\\_Healthcare\\_Laying\\_Foundation.pdf](http://www3.weforum.org/docs/WEF_Insight_Report_Value_Healthcare_Laying_Foundation.pdf).

# Meeting Grand Challenges: Assessment of Horizon 2020 Health, Demographic Change and Wellbeing Projects

*Małgorzata Stefania Lewandowska*

## Abstract

In Horizon 2020, the biggest European Union research and innovation funding program with of budget of nearly €80 billion for the period 2014–2020, one of challenges is Health, Demographic Change and Wellbeing which “aims to keep older people active and independent for longer and support the development of new, safer and more effective interventions. [It] also contributes to the sustainability of health and care systems” (EuroAccess, 2022). The aim of this chapter is to investigate how effective the European Union investments are, taking into account the measurable outcomes in accordance with the expected targets. The analysis is based on the input financial data obtained from EU Contact Points covering 314 Health projects completed by December 2020. The output data are divided into four groups: economic (patents, prototypes); academic (publications, PhD dissertations), health (new drugs, new healthcare solutions, final reports, conferences), and media (press releases). Data are collected in the Cordis project database and matched with financial data. The results show that such an assessment has multiple drawbacks and does not provide a rich picture of the program outcomes, leading to the conclusion that more advanced and holistic techniques have to be implemented, especially those based on big data analysis.

## Keywords

European Union – Horizon 2020 – health – projects assessment – financial data – big data analysis

## 1 Introduction

The objectives of the EU Framework Programmes for Research and Innovation presented in the first Framework Programme (FP1) in 1984 as well as in subsequent programs (such as enhancement of Europe's competitiveness, creation of the knowledge-based economy, contribution to the realization of the Single Market, achievement of sustainable development, economic growth, and an inclusive and user-friendly information society) (EPEC, 2011), serve as instruments for the implementation at the EU level of a strategy for the development of R&D activities facing Societal Challenges (European Commission, 2012).

These are described in the Lund Declaration (Lund Declaration, 2009), which states that the European research community “has put much emphasis on the necessity (...) to respond to the Grand Challenges of our times” (Chuberre & Liolis, 2010).

Horizon 2020 (H2020), the biggest EU research and innovation funding program with a budget of nearly €80 billion for the period 2014 to 2020, is structured around Grand or Societal Challenges (European Commission, 2020a), which goes in line with previous suggestions put forward by many researchers and policy-makers (ERA Rationales Group, 2007; Georghiou, 2008; European Commission, 2009), and emphasizes challenges such as:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture and forestry, marine and maritime and inland water research, and the bioeconomy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Climate action, environment, resource efficiency and raw materials;
- Europe in a changing world inclusive, innovative and reflective societies;
- Secure societies – protecting freedom and security of Europe and its citizens.

As the timeframe of H2020 has already ended, and it can be expected that most of the financed projects can be already evaluated, the purpose of this chapter is to assess H2020 Health, Demographic Change and Wellbeing program effects measured by outputs divided into four groups: economic, academic, health, and social media, using officially available data. The obtained results, which grasp only partly the possible impact of the financed projects, call for a holistic approach, which may potentially deliver more accurate data on the effects of public policy, with Horizon 2000 being one of its tools.

## 2 Theoretical Background

### 2.1 *Rationale for the Government Intervention*

The significance of innovation in enhancing the efficacy of businesses and economic growth of countries is the most compelling argument for government policy to promote innovation (Crépon, Duguet, & Mairesse, 1998; Van Leeuwen & Klomp, 2006). At both the macro- and microeconomic levels, innovation is a critical component of international competitiveness (Brusoni, Cefis, & Orsenigo, 2006; Halpern, 2007), while technological gap theory suggests that innovation is a critical component of international competitiveness at the sector level (Posner, 1961; Soete, 1981).

According to economic theory (Nelson, 1959; Arrow, 1962), a firm will not invest in innovation unless it can capture and take advantage of all of the benefits (Luukkonen, 2000).

Innovation policy, which is a component of the state's economic policy, is a system of public administration activities (at various levels – national, regional, and local) that promote the development of new solutions, as well as their dissemination and implementation (Weresa, 2014, p. 87). Two premises underpin the rationality of the innovation policy: market failure and system failure (de Jong et al., 2008; de Jong et al., 2010).

Market failure manifests itself in the following elements: limited intellectual property protection, uncertainty associated with a high probability of failure of an innovative project, limited divisibility of a process that requires a relatively smooth and uninterrupted inflow of funds, and information asymmetry (von Hippel, de Monaco, & de Jong, 2014).

The failure of the market justifies the use of novel policy tools such as R&D subsidies, basic research support at universities or research institutes, and the establishment of an intellectual property protection system. In the case of market failure caused by individual innovators' unwillingness to share innovation with its adapters, it is critical to promote cooperation in innovation, which allows the costs of innovation as well as potential benefits to be shared at an earlier stage of the process (de Jong et al., 2015).

The most frequently mentioned factors influencing system failure and justifying state intervention are: insufficient innovative abilities of innovation system participants – enterprises, research institutes, venture capital availability; insufficient cooperation skills, which are not always self-contained and sometimes need to be stimulated. The final component is the unreliability of the system's framework, which includes elements such as values and norms, as well as consumer demand.

In this context, innovation policy has to affect an increasing number of areas of business activity, as well as new groups of enterprises (OECD, 2005).

This, in turn, leads to an increase in the number of influence tools used by decision-makers, which can be classified into four categories: regulations (legal regulations, norms, standards, prohibitions, and limits); systemic instruments (statutory financial incentives); government programs and projects (including public procurement); and instruments supporting organizations intermediating in innovation processes (Jasiński, 2010; Jasiński, 2013; Jasiński, 2014, p. 76).

There is a general assumption among decision-makers that increased public support for R&D activities leads to an increase in R&D expenditure in an organization and, as a result, an increase in its level of innovativeness. It is especially important, as according to studies on innovation, one of the greatest impediment to its introduction is a lack of financial resources within the enterprise (Guijarro-Madrid, Garcia, & Van Auken, 2009; Watkins & Paff, 2009; Lewandowska, 2012; Madeira, 2017; Moura et al. 2019).

The government can help businesses via a variety of tools, including grants, loans, subsidies, preferential loans, loan guarantees, tax reductions, and tax deferral.

Grants do not come without drawbacks, such as asymmetry of knowledge between an innovator and a government agency, costly procedures, corruption, and, in many cases, political pressure (Czarnitzki, Hamel, & Rosa, 2011; Czarnitzki & Lopes-Bento, 2014; Hünermund & Czarnitzki, 2019).

Incentives and tax credits (deferrals in paying taxes and tax credits for R&D, enabling the reduction of burden on remuneration related to R&D activity, preferential rates on royalties and other income related to knowledge resources) can be used as market tools to reduce the marginal costs of R&D activities. As it does not need arbitrary decisions about the distribution of support to individual sectors of the economy, industries, and firms, this method of solving the challenge of financing innovation may be more effective than direct support for R&D operations. As a result, more businesses are motivated to innovate (OECD, 2012; Gande et al., 2020; Gaessler, Hall, & Harhoff, 2021; Ivus, Jose, & Sharma, 2021). Unfortunately, in the Covid pandemic era, traditional tools to deal with market failures seem to be no longer adequate, and in order to progress the economy, a new concept, called the “Entrepreneurial State” (Mazzucato, 2013), must be put in place, which means that governments are engaged in the process of bringing new products and services to market and creating a market rather than merely holding the current market in place (Mazzucato, 2018; 2019; Mazzucato, 2021).

Thus, a challenge-based approach, creation of markets, and integration of supply and demand-side policies are the three central ideas of mission-oriented policies (Georghiou, 2008). Orienting policy toward a specific mission necessitates the adoption of two factors (European Commission, 2017a). The first and foremost requirement is accountability. Whatever the mission, the institution

that has been “mandated” to carry it out should be held accountable for the decisions made, the processes followed, and the outcomes obtained. Measurability is a second, related component. Keeping track of whether the task is being completed, especially if goals have been defined, provides for more precise and accurate assignment of responsibility. This calls for designing a holistic, new approach of evaluation of the results and impact of H2020 financing.

## 2.2 *Horizon 2020: An Overview*

The Europe 2020 strategy, which defines the development paths of European Union member states, identifies three mutually reinforcing priorities: smart, sustainable, and inclusive growth. The Horizon 2020 Framework Programme for Research and Innovation (2014–2020), established on 11 December 2013 by Regulation No. 1291/2013 of the European Parliament and of the Council, is a major program for financing research and innovation in the European Union and is part of this strategy.

The goal of H2020 is to develop European innovations of global significance and to build a competitive advantage for the European economy based on innovations in line with the Europe 2020 strategy and the Innovation Union initiative.

The Horizon 2020 combines three previously separate research support programs:

- the 7th Framework Programme for Research, Technological Development, and Demonstration Activities;
- an innovation-focused component of the Framework Programme for Competitiveness and Innovation (CIP) for 2007–2013; and
- the work of the European Institute of Innovation and Technology.

It combines research and innovation with an emphasis on three key areas: “Excellent Science,” “Industrial Leadership,” “Societal Challenges,” and two additional priorities: Access to Risk Finance and Innovation in SME (European Commission, 2017). These key pillars are supplemented by specific objectives such as “Excellence and Broadening Participation,” “Science with and for Society,” and the work of the Joint Research Centre and the European Institute of Innovation and Technology.

## 2.3 *Indicator-Based Approach as a Tool to Assess Results of Innovation Policy*

An indicator is defined as “a parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area with a significance extending beyond that directly associated with a parameter value” (OECD, 1993). Indicators have two purposes: they summarize information and can be used to explain complicated



phenomena to many stakeholders in a simplified form. There are various types of indicators that can be used to monitor and evaluate the performance of H2020 participants.

Generally, there are six different sorts of indicators: inputs, activities, throughput/outputs, immediate outcomes, intermediate outcomes, and ultimate outcomes. These indicators track the progression of the results chain.

The inputs, activities, and throughput/outputs of an investment address the “how” of an investment, whereas the varied outcomes represent the actual “changes” that occur: the development results. Financial, human, material, and information resources can all be used as inputs. Activities are actions taken in order to mobilize inputs and produce outcomes.

Throughputs and outputs are the indirect and direct results of an initiative’s activities. Immediate results (short-term outcomes) are changes that can be instantly attributed to an initiative’s outputs. Intermediate outcomes (medium-term outcomes) are improvements that are typically reached toward the end of a project and typically involve a beneficial behavior/practice change. The ultimate outcome (the purpose for an initiative) is the maximum level of change that can be legitimately assigned to the initiative in a casual manner, and it is the result of one or more intermediate results (European Commission, 2015). Indicators of efficiency represent the ratio of inputs required per unit of output produced. Indicators of effectiveness demonstrate the ratio of outputs required to generate one unit of outcome, or the extent to which outputs influence outcomes. The persistence of outcomes across time is measured by sustainability indicators. The evaluation of effectiveness and efficiency levels depends on the organization’s strategy and the aim to achieve (Etzkowitz & Leydesdorff, 2000; Laliene & Sakalas, 2014).

### 3 Assessment of Horizon 2020 Health, Demographic Change and Wellbeing Projects

#### 3.1 *Aims and Scope of Horizon 2020 Health, Demographic Change and Wellbeing*

Nowadays Europe is confronted with four major healthcare challenges: (i) the increase in chronic diseases combined with an aging population and increasing societal demands; (ii) the influence of external environmental factors such as climate change; (iii) inequalities in healthcare access and (iii) the risk of losing the ability to protect the populations against the threats of infectious diseases, such as the Covid pandemic (European Commission, 2020b).

Thus, the H2020 Health component aims to keep older people active and independent for longer and support the development of new, safer, and more effective interventions. It also contributes to the sustainability of health and care systems.

The obstacles to achieving these goals include decreases in the number of people employed, population, and labor productivity, which increase public spending (European Commission, 2017).

H2020 Health, Demographic Change and Wellbeing was divided into three Work Programmes: 2014–2015; 2016–2107; 2018–2020.

For the years 2014 and 2015, the Horizon 2020 societal challenge of “Health, demographic change, and wellbeing” included 34 topics in the “personalizing health and care” focus area call and 16 topics in the “coordination activities” call. Eight additional actions designed to support the implementation of the challenge were also included, which were not subject to competitive calls for proposals.

For the Health, Demographic Change and Wellbeing Work Programme 2016–2017, the overall strategic focus was on the promotion of healthy aging and personalized healthcare. Research priorities included “personalized medicine, rare diseases, human bio-monitoring, mental health, comparative effectiveness research, advanced technologies, e/m-health, robotics, patient empowerment, active and healthy ageing, data security, big data, valorization, anti-microbial resistance, infectious diseases including vaccines, maternal and child health and the silver economy.” By aligning organizational priorities with evidence-based policies based on scientific research data, ICT solutions, and best practices in interventions, a faster development of evidence-based health and care policies is expected (European Commission, 2017).

The last Work Programme 2019–2020 incorporated numerous broad recommendations made in the Horizon 2020 interim evaluation, such as increasing social involvement and impact.

### 3.2 *An Overview of Horizon 2020 Health, Demographic Change and Wellbeing Projects Based on Financial Data*

According to financial data obtained from European Union Contact Points, until December 2020 there were 26,629 projects accepted under the whole Horizon 2000 program, with 138,875 participants. The total financing amounted to € 1,032,697,991,384, with the total project budget of €1,487,187,308,269. The average financing per participant was €7,436,169. These data are for both completed and still ongoing projects.

It is worth understanding the meaning of the term “participant.” One or more applying institutions submit a proposal to the European Commission to finance a project. If the proposal is accepted, it becomes a project that is carried out by one or more participants. A participant may be involved in more than one project, which is why the concept of “participations” exists (European Commission, 2014). Thus, “the number of participations,” or the number of grants awarded, does not directly translate into the number of organizations receiving co-financing because an organization can apply for co-financing multiple times.

The projects dealing with Health constitute 4% (1,045 in numbers) of the total number of H2020 projects, the share of participants was 7% (10,219 in numbers), the total financing was 9% of all H2020 projects (€98,103,433,963), with the total project budget of 10% (€150,007,185,986).

The average financing per participant in H2020 projects was €7,436,169 whereas for Health projects it was higher at €9,600,101. Further details are presented in Table 6.1.

As Figure 6.1 shows, the biggest beneficiaries of the H2020 Health funds, are the United Kingdom (€13,834,966,846), Germany (€13,423,309,892), France (€11,512,294,925), Spain (€9,703,927,696), Italy (€9,276,718,354), the Netherlands (€9,168,576,261), and Belgium (€6,757,710,382). There is a visible and striking difference between these old member states and the new ones, which are strongly lagging behind.

TABLE 6.1 Horizon 2020 and H2020 health, demographic change and wellbeing projects in numbers – data for period ended December 2020

H2020	Number of projects	Number of participants	Total EU funding	Total project budget	Average funding per participant
Total H2020	26,629	138,875	€1,032,697,991,384	€1,487,187,308,269	€7,436,169
H2020 Health	1,045	10,219	€98,103,433,963	€150,007,185,986	€9,600,101
Health part of H2020	4%	7%	9%	10%	

SOURCE: AUTHOR'S ELABORATION BASED ON DATA FROM EUROPEAN UNION CONTACT POINTS

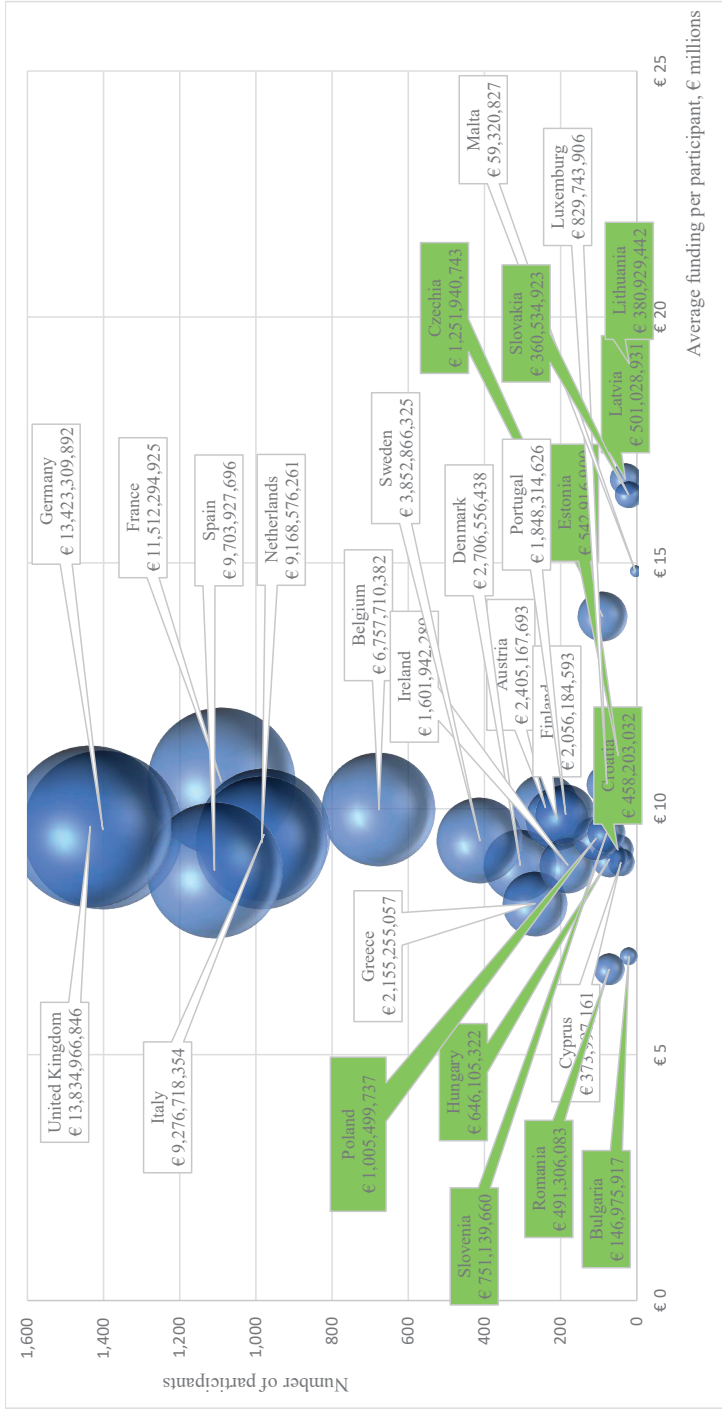


FIGURE 6.1 H2020 health, demographic change and wellbeing projects, by European Union country, completed and ongoing, data for period ended December 2020

SOURCE: AUTHOR'S ELABORATION BASED ON FINANCIAL DATA FROM EU CONTACT POINTS

### 3.3 *Key Performance Indicators for Horizon 2020 Societal Challenges Set by European Union*

Horizon 2020 marks a move toward the use of indicators to track outcomes and impacts. There has traditionally been a focus on examining participant characteristics, R&D inputs, and EU-funded project outputs in evaluating the success of the Framework Programmes for Research. In Horizon 2020, more attention will be paid to measuring the program's effects and their economic and social impact on Europe, particularly in the fields of science and technology (Horizon 2020 Indicators, 2015).

Key Performance Indicators were identified prior to the start of the Framework Programme, providing a solid foundation for the monitoring and evaluation of Horizon 2020, as well as a focus on measuring the results and impacts of the program.

For all Societal Challenges, including Health projects, the key performance indicators are as follows:

- Patent applications and patents awarded in the area of the different Societal Challenges
- Publications in peer-reviewed high impact journals in the area of the different Societal Challenges
- Number of prototypes and testing activities
- Number of joint public-private publications
- New products, processes, and methods launched into the market.

The European Union set specific targets for two of these five indicators.

For patents, the target is 2 per €10 million funding (2014–2020) and for publications, it is set at 20 per €10 million funding (for all Societal Challenges).

For the three remaining indicators, the target was expected “to be developed on the basis of first Horizon 2020 results,” but there is no source available with these targets set to date. For details see Table 6.2.

### 3.4 *Preliminary Evaluation of H2020 Health, Demographic Change and Wellbeing Projects*

The pilot evaluation of the H2020 Health, Demographic Change and Wellbeing projects is based on the input-output method of analysis. The efficiency analysis is also provided for selected indicators.

The input data, which are mainly financial, are obtained from EU Contact Points at the project level, whereas data on the indicators are retrieved from CORDIS (Community Research and Development Information Service for Science), where details of all EU-funded research projects and their outcomes are made publicly available. The database encompasses 100,000 project cases that stretch all the way back to the very first Framework Programme.

TABLE 6.2 Key performance indicators for H2020 societal challenges set by the European Union

Key performance indicator	Definition of the indicator	Type of data required	Target at the end of H2020
Societal Challenges – Publications in peer-reviewed high impact journals in the area of the different Societal Challenges	The percentage of publications published in the top 10% impact ranked journals by subject category	Publications from relevant funded projects (DOI: Digital Object Identifiers); Journal impact benchmark (ranking) data to be collected by commercially available bibliometric databases	On average, 20 publications per €10 million funding (for all societal challenges)
Societal Challenges – Patent applications and patents awarded in the area of the different Societal Challenges	Number of patent applications by theme	Number of awarded patents by theme	2 per €10 million funding (2014–2020)
Societal Challenges – Number of prototypes and testing activities	Number of prototypes, testing (feasibility/demo) activities, clinical trials	Reports on prototypes, and testing activities, clinical trials	[To be developed on the basis of first Horizon 2020 results]
Societal Challenges – Number of joint public-private publications	Number and percentage of joint public-private publications out of all relevant publications	Properly flagged publications data (DOI) from relevant funded projects	[To be developed on the basis of first Horizon 2020 results]
New products, processes, and methods launched into the market	Number of projects with new innovative products, processes and methods	Project count and drop down list allowing to choose the type processes, products and methods	[To be developed on the basis of first Horizon 2020 results]

SOURCE: BASED ON EUROPEAN COMMISSION (2015)

Table 6.3 presents the methodology of data collection for H2020 Health, Demographic Change and Wellbeing projects completed by December 2020. The starting point for the research was the list of N = 480 Health, Demographic Change and Wellbeing projects completed by December 2020 obtained from EU Contact Point. Out of this list, N = 314 projects were extracted, where the information about the throughput/output indicators in the Cordis database was fully available.

This number constitutes 30% of all Health, Demographic Change and Wellbeing projects, that is, EU funding of €606,357,424, with total project budget of €735,209,023.

The throughput/output results of these N = 314 Health, Demographic Change and Wellbeing projects were as follows:

- economic: 4 patent filings, 135 demonstrators, pilots and prototypes;
- academic: 1680 articles, 68 book chapters, 5 monographic books, 20 theses/dissertations;

TABLE 6.3 Methodology of data collection for the assessment of H2020 health projects completed by December 2020

No.	Project ID	Acronym	Time frame	EU funding (euros)	Project budget (euros)	Number of participants
1	115842	VSV-EBOVAC	48	3,887,260.00,	4,786,010.00,	13
2	115843	EbolaMoDRAD	36	4,300,935.00,	4,300,935.00,	18
3	115844	FILODIAG	35	2,260,105.00,	2,260,105.00,	4
4	115848	Mofina	27	1,162,622.00,	4,398,252.00,	6
5	115850	EBOMAN	36	1,023,325.00,	40,188,229.00,	3
6	115890	ADAPT-SMART	34	1,130,000.00,	4,064,146.00,	35
7	115916	PRISM	42	8,080,000.00,	16,195,875.00,	24
8	115985	MOPEAD	39	2,043,000.00,	4,581,967.80,	16
9	116020	ROADMAP	24	3,998,250.00,	8,210,381.00,	26
10	116055	DO-IT	24	3,549,833.00,	7,191,755.00,	36
11	116072	NGN-PET	36	1,500,000.00,	3,050,000.00,	6
12	633196	CATCH ME	48	4,944,773.00,	4,944,773.00,	11
13	633212	ALEC	48	5,534,094.25,	7,271,433.75,	13

SOURCE: AUTHOR'S ELABORATION BASED ON DATA OBTAINED FROM EUROPEAN UNION CONTACT POINTS MATCHED WITH DATA FROM THE CORDIS DATABASE

- health: 1517 documents/reports, 104 websites, platforms, portals, 115 datasets via the OpenAIRE repository, 901 conference proceedings; and
- media: 105 videos produced.

There were 164 projects where the only output was periodic reporting. For details see Figure 6.2.

Out of these 11 identified indicators, only two of them: economic (patent applications) and academic (articles) have their targets, which means that the European Union sets the exact level of spending that has to produce a certain number of patent or articles.

For patents, there should be an average of 2 per €10 million funding (2014–2020), which means that the “cost” of one patent for the European Union as the “investor” is €5,000,000.

For publications, there should be an average of 20 per €10 million funding (for all Societal Challenges), which means, that the “price” of one publication that is “paid” by European Union is €500,000. It is important to note, that such

<i>Documents/ reports/other</i>	<i>Websites/platforms/ portals</i>	<i>Articles</i>	<i>Media videos movies other</i>	<i>Pilots prototypes</i>	<i>Patent applications</i>	<i>Book chapters</i>	<i>Conference proceedings other</i>	<i>Datasets via OpenAIRE</i>	<i>Monographic books</i>	<i>Theses/dissertations</i>	<i>Periodic reporting only</i>
5	1	6									
6		16	2					2			
1			1	1	2	1	7				
		2									
2	1	3					1				
34	1	3					1				
11	1	17	4				2				
20		1									
29	1	10									
27		2					3				
4		1					9				
2	1	50	3					1			
4	1	29						1			



Number of completed projects with full data available	EU funding	Total budget of projects	Number of entities funded
314	€606,357,424	€735,209,023	1,788

ECONOMIC				ACADEMIC				HEALTH				MEDIA	
Patent applications	Demonstrators	Articles	Book chapters	Monographic books	Theses/dissertations	Documents Reports	Periodic Reporting only	Websites Platforms	Datasets	Conference Proceedings	Media Videos	Other	105
4	135	1,680	68	5	20	1,517	164	104	115	901	901	105	105

FIGURE 6.2 Input and output analysis of H2o2o health, demographic change and wellbeing projects, data for period ended December 2020  
 SOURCE: AUTHOR'S ELABORATION BASED ON DATA OBTAINED FROM EUROPEAN UNION CONTACT POINTS MATCHED WITH DATA FROM CORDIS

a publication should appear in peer-reviewed high impact journals in the area of the different Societal Challenges.

Unfortunately, as regards the number of prototypes and testing activities; the number of joint public-private publications; new products, processes, and methods launched into the market, even though it is said that the target is “to be developed on the basis of first Horizon 2020 results,” there is no available publication with these data officially accessible. That is why any further investigation is complicated, as the only measurable outcomes are those for patents and publications.

In the list of  $N = 314$  projects, there were  $N = 3$  projects where patents were registered. The lowest “price” for a patent was €1,130,053 and the highest €4,234,330, which was still below the target set by the European Union at €5,000,000.

Out of the list of  $N = 314$  projects completed by December 2020, in  $N = 113$  selected H2020 Health, Demographic Change and Wellbeing projects with the financing of €487,585,975, there were 1,680 articles published at the average “cost” of €290,230, which seems to be low given the target set by EU at €500,000. One has to remember, however, that such a target is set for “publications in peer-reviewed high impact journals in the area of the different Societal Challenges” and in our research we took into account all the published articles, regardless of their quality and impact of journals.

There are striking difference in the number of articles published as the outcome of H2020 Health projects. There was one project with funding of €5,917,266, where 214 articles were published (which means the “average cost” of €27,658). It is hard to believe that all of them were published in high ranked journals. On the other hand there was one project with EU funding of €15,153,216 which “produced” only two articles, 5 documents and one website, which puts the “cost” of one publication at €7,576,608.

The details concerning the exact numbers are presented in Table 6.4.

#### 4 Holistic Approach to Impact Assessment of H2020 Health Projects

In our opinion, the results obtained based on the input-output method and efficiency indicators do not provide sufficient information about attained objectives of the H2020 Health, Demographic Change and Wellbeing projects; what is more, they do not deliver data on the impact of the projects. We do believe that only a holistic approach to these issues, where mixed evaluation methods are used, would bring expected results.

TABLE 6.4 Efficiency indicators for H2o2o health, demographic change and wellbeing projects, data for period ended December 2020

No of project with particular indicator	EU funding (€)	Total budget (€)	Number of entities	Patent applications	Average "cost" of patent application (€)	Target set by European Union (€)	Highest "cost" of patent application (€)	Lowest "cost" of patent application (€)
1	2,260,105	2,260,105	4	2	1,130,053 (with 1 prototype)	5,000,000		1,130,053 (with 1 prototype)
1	5,999,756,	7,259,113.16,	17	1	5,999,756 (with 47 publications)	5,000,000	4,234,330 (with 1 prototype)	
1	4,234,330,	5,537,142.50,	12	1	4,234,330 (with 1 prototype)	5,000,000	4,234,330 (with 1 prototype)	
No of projects with particular indicator	EU funding	Total budget	Number of entities	Articles	Average "cost" of article	Target set by European Union	Highest "cost" of article	Lowest "cost" of article
113	487,585,975	601,481,243	1,369	1,680	290,230 (with 129 prototypes)	500,000	7,576,608	27,651

SOURCE: AUTHOR'S ELABORATION BASED ON DATA OBTAINED FROM EUROPEAN UNION CONTACT POINTS MATCHED WITH DATA FROM CORDIS

The Interim Evaluation of Horizon 2020 (European Commission, 2017) presents a highly advanced model with 18 in-depth methods covering: expert groups, case studies, surveys, interviews, text mining, statistical analysis, documentary reviews, internal assessments, bibliometric analysis, patent analysis and social network analysis, which is far more advanced than the one presented here. Its weakness is that it needs extensive surveys, which is a costly exercise and requires a huge number of people to be involved. The presented approach is based solely on publicly available data.

The logic of the author's proposed assessment methodology is presented in Figure 6.3.

*In Step 1*, the H2020 Health, Demographic Change and Wellbeing rationale should be presented. The main source of knowledge here is data from H2020 web pages, related documents, and the Health Work Programmes 2014–2016, 2016–2017, and 2018–2020. This is similar to what is presented in this chapter, although, using a big data analysis, mapping of the goals and scopes of the program can be put forward. Content data from calls has to be gathered here as well.

*In Step 2*, input data should be investigated. This is what has also been done in this chapter but only regarding the financial data. The input data obtained from EU Contact Points are in fact mainly financial data covering issues such as: EU funds per project; funds per project per entity; total sum of the project; call type; but also project duration; type of entities, number of entities involved; coordinator. What can be done here is the ranking of the entities involved, for example based on university rankings, which may provide some qualitative assessment on the potential leverage effect, based on financial data, with some references to non-financial data.

*In Step 3*, throughput and output data should be gathered and analyzed. They should be categorized, similarly to what is presented here, into four groups: economic (patents, prototypes, etc.); academic (publications, dissertations), health (new drugs, new healthcare solutions, final reports, conferences), and media (press releases). Data (number of outcomes) should be collected on the project basis (one by one) from Cordis and OpenAIRE, and matched with the financial data gathered in Step 2. This allows the proportion of the invested funds to the measurable outcomes to be measured against the expected outcomes set by the European Union. A qualitative analysis should be performed especially for publications in order to investigate whether the publications meet the targets set by the European Union. Big data analytics should be applied here in order to capture the areas covered by the publications under study.

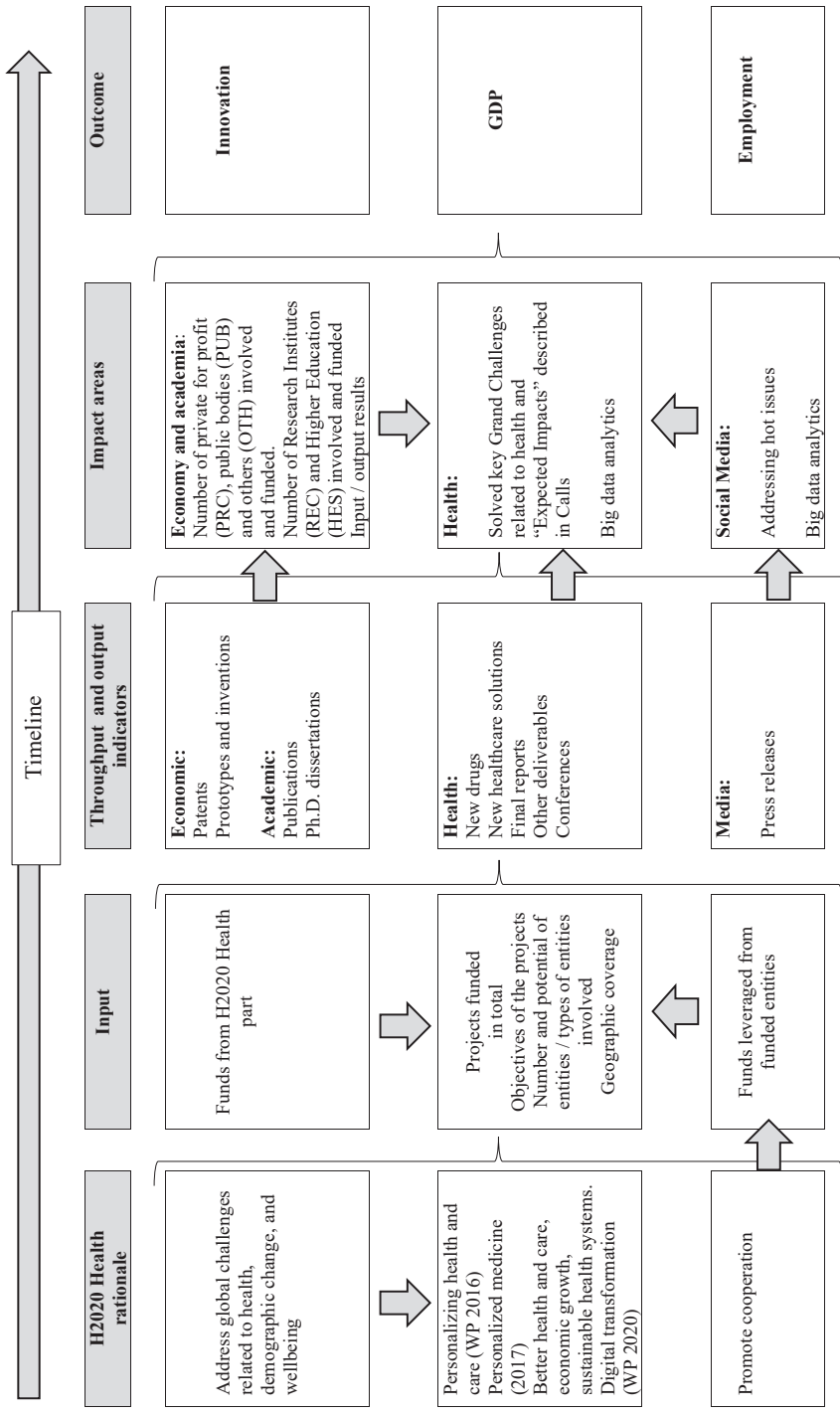


FIGURE 6.3 Holistic assessment of H2020 health, demographic change and wellbeing societal challenge  
SOURCE: AUTHOR'S ELABORATION

*In Step 4*, impact areas should be investigated using mixed methods. In the Economy and Academia part, the starting point are financial data (EU funds) for Private for Profit (PRC), Public Bodies (PUB) and Others (OTH) entities broken down between the countries identified in Step 1 and accompanied by qualitative characteristics of all the entities based on rankings, financial data, and so on. Using the input-output analysis based on funding data for particular entities from different countries representing specific qualitative characteristics, the impact of funding would be calculated for each EU country.

A similar analysis will be carried out for academia entities – Research Institutes (REC) and Higher Education (HES).

In the Health part, big data analytics would be performed for the content (text) of goals/objectives, final reports and other available information gathered in Step 3. The results obtained would be plotted on maps constructed based on the calls in Step 1. This would show to what extent the completed projects meet the scope and aims of H2020 Health, Demographic Change and Wellbeing.

In the Social Media part, a similar approach would be implemented. Based on the data gathered from the internet, the area of interest would be described (another big data approach) and plotted with the data on press release content from Step 3.

The operationalization of data and the method applied are explained in Table 6.5.

TABLE 6.5 Description of the steps to be followed in holistic assessment, operationalization of the indicators, method applied

Step	Indicators	Data collection	Method of analysis
1	H2020 Health rationale	H2020 website; Horizon 2020 Health Work programmes 2014–2015; 2016–2017; 2018–2020	Big data (text) mining in order to map aims
1	H2020 Health rationale	Content data from calls	Big data (text) mining in order to map aims
2	Input data	Financial data from Cordis; EU Contact Points, data on beneficiaries	Linking financial data with qualitative data of beneficiaries in order to calculate the potential leverage effect
3	Throughput; output indicators	Cordis, OpenAIRE data on publications, patents	

TABLE 6.5 Description of the steps to be followed in holistic assessment (*cont.*)

Step	Indicators	Data collection	Method of analysis
3		Content of final reports and other deliverables	Big data (text) mining
4	Impact area – economy	Financial data from contact points used to calculate economic impact by funded private for profit organizations (PRC), public bodies (PUB) and others (OTH) on economy (input/output)	Input/output analysis Geographical spread
4	Impact area – academia	Financial data from contact points used to calculate economic impact by funded Research Institutes (REC) and Higher Education (HES) on academia (input/output)	Input/output analysis Geographical spread
4	Impact area – health	All calls already covered in H2020 Health used to map Grand Challenges and plotted with data from final reports of H2020 Health projects	Big data (text) mining
4	Impact area – social media	Data from internet related to health issues used to map areas of interest related to Health and contrasted with data from press releases produced by H2020 health projects	Big data (text) mining

SOURCE FOR FIGURE 6.3 AND TABLE 6.5: AUTHOR'S ELABORATION

The proposed methodology is universal and can be used not only to assess Health projects, but also any other projects funded under Horizon 2020.

## 5 Conclusions

The goal of this chapter was to provide a comprehensive overview of the Horizon 2020 Health, Demographic Change, and Wellbeing projects, as well as to deliver a preliminary assessment of how effective European Union investments are in terms of measurable outcomes in accordance with projected goals.

Health, Demographic Change, and Wellbeing projects account for 9% of the whole H2020 financing with 10,219 participants involved (by December 2020).

Based on the financial data of the completed as well as ongoing projects, it was shown that there is a striking discrepancy in the allocation of the EU Health, Demographic Change and Wellbeing funds between Western European and Central and East European countries. In order to cope with this inequality, a policy aimed at active cooperation between research organizations from the EU15 and the EU13 should be implemented. This should lead to stronger involvement of EU13 participants. Otherwise, the gap in innovation ability between the EU MS will rise.

In a further step of the research, conducted on  $N = 314$  projects completed by December 2020, it was proved, that with the total funding of €606,357,424, there were only 4 patent applications, whereas the number of prototypes reached 135. This shows a potential which is not ultimately converted into a finalized output that has a commercial (marketable) value.

For academic outputs, the situation looks better, as there were 1,680 publications reported, but it was not further investigated if those were works of the highest quality according to the target set by European Union.

For health and media outputs, a massive number was produced: 1,517 documents and reports, 104 website platforms, 115 data sets; 901 conference proceedings, 105 video movies, but in order to assess their quality, a more detailed research is needed.

The lack of qualitative measurement is the serious limitation of this research and the input-output analysis itself, which has been conducted here. One of the solutions may be to base the “value” of a publication on the number of citations, but this requires a follow-up analysis to be introduced.

Such ex-post evaluation should be conducted two or three years after the funding program ends, as was the case with the evaluation of FP7 (Interim Evaluation of Horizon 2020, 2017).

In order to overcome these serious obstacles, a more comprehensive methodology, based mainly on big data (text) mining is proposed and explained. It is universal and can be implemented for other Horizon 2020 projects.

The implementation of such a methodology calls for a more open policy to be embarked on by the European Union, where data would be available at the project level and accessible in an easier and more user-friendly way. Such change in data availability as well as assessment methodology is needed now but also for the future, as many researchers and policy-makers underline the imperative to shift the focus from R&D inputs to the whole impact of complex systemic interactions involving basic and applied research, development, innovation, diffusion, and all the associated spill-overs, and as a result the



implementation of a mission-oriented R&D policy (European Commission, 2017a, p. 8).

## References

- Arrow, K. J. (1962). Economic welfare and the allocation of resources for invention. In R. R. Nelson (Ed.), *The rate and direction of inventive activity: Economic and social factors*. National Bureau of Economic Research, Conference Series (pp. 609–625). Princeton University Press.
- Brusoni, S., Cefis, E., & Orsenigo, L. (2006). *Innovate or die? A critical review of the literature on innovation and performance*, Working Paper No. 179. CESPRI, Università Commerciale Luigi Bocconi.
- Chuberre, N., & Liolis, K. (2010). *Contribution to Grand Societal Challenges*. Integral SatCom Initiative. Retrieved January 7, 2021, from [http://ec.europa.eu/invest-in-research/pdf/download\\_en/isi\\_contribution.pdf](http://ec.europa.eu/invest-in-research/pdf/download_en/isi_contribution.pdf).
- Crepon, B., Duguet, E., & Mairesse, J. (1998). Research, Innovation and Productivity: An Econometric Analysis at the Firm Level. *Economics of Innovation and New Technology*, 7, 115–158.
- Czarnitzki, D. & Lopes-Bento, C. (2014). Innovation subsidies: Does the funding source matter for innovation intensity and performance? Empirical evidence from Germany. *Industry & Innovation*, 21(5), 380–409.
- Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconomic study on Canadian firms. *Research Policy*, 40(2), 217–229.
- de Jong, J. P. J., Kalvet, T., & Vanhaverbeke, V. (2010). Exploring a theoretical framework to structure the public policy implications of open innovation. *Technology Analysis & Strategic Management*, 22(8), 877–896.
- de Jong, J. P. J., Vanhaverbeke, V., Kalvet, T., & Chesbrough, H. (2008). *Policies for open innovation: Theory, framework and cases*. VISION Era-Net.
- de Jong, J. P. J., von Hippel, E., Gault, F., Kuusisto, J., & Raasch, Ch. (2015). Market failure in the diffusion of consumer-developed innovations: Patterns in Finland. *Research Policy*, 44(10), 1856–1865.
- EPEC. (2011). *Understanding the long term impact of the Framework Programme. Evaluating the long term impact of Framework Programme research – Final Report*. Retrieved June 6, 2021, from [http://ec.europa.eu/research/evaluations/pdf/archive/other\\_reports\\_studies\\_and\\_documents/long\\_term\\_impact\\_of\\_the\\_fp.pdf](http://ec.europa.eu/research/evaluations/pdf/archive/other_reports_studies_and_documents/long_term_impact_of_the_fp.pdf).
- ERA Rationale Group. (2007). *Challenging Europe's research: Rationales for the European Research Area (ERA). Report of the ERA Expert Group*. Retrieved August 12, 2021, from [https://ec.europa.eu/research/era/pdf/eg7-era-rationales-final-report\\_en.pdf](https://ec.europa.eu/research/era/pdf/eg7-era-rationales-final-report_en.pdf).

- Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research Policy*, 29, 109–123.
- EuroAccess. (2022). *Programme: Health, Demographic Change and Wellbeing*. Retrieved March 11, 2022, from [https://www.euro-access.eu/programm/health\\_demographic\\_change\\_and\\_wellbeing](https://www.euro-access.eu/programm/health_demographic_change_and_wellbeing).
- European Commission. (2015). *Horizon 2020 indicators. Assessing the results and impact of Horizon 2020*. Retrieved May 17, 2021, from <https://op.europa.eu/en/publication-detail/-/publication/68686e76-8f53-11e5-983e-01aa75ed71a1>.
- European Commission. (2017). *Interim evaluation of Horizon 2020*. Retrieved August 11, 2021, from <https://op.europa.eu/en/publication-detail/-/publication/fad8c173-7e42-11e7-b5c6-01aa75ed71a1/language-en/format-PDF/source-77918455>.
- European Commission. (2020a). *Horizon 2020*. Retrieved January 7, 2021, from <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/societal-challenges>.
- European Commission. (2009). *The Role of community research policy in the knowledge-based economy. Expert Group report*. Retrieved August 10, 2021, from <https://op.europa.eu/en/publication-detail/-/publication/8edc4431-c8e7-49ba-a98a-ba0dc91ca13/language-en>.
- European Commission. (2012). *The Grand Challenge. The design and societal impact of Horizon 2020*. Retrieved June 7, 2021, from <https://ec.europa.eu/programmes/horizon2020/en/news/grand-challenge-design-and-societal-impact-horizon-2020>.
- European Commission. (2013). *Horizon 2020. Work Programme 2014–2015*. Retrieved May 1, 2021, from [https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014\\_2015/main/h2020-wp1415-health\\_en.pdf](https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-health_en.pdf).
- European Commission. (2017a). *Towards a mission-oriented research and innovation policy in the European Union. An ESIR Memorandum*. Retrieved August 12, 2021, from <https://op.europa.eu/en/publication-detail/-/publication/4177ae56-2284-11e8-ac73-01aa75ed71a1/language-en>.
- European Commission. (2017b). *Work Programme 2016–2017*. Retrieved May 1, 2021, from [https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016\\_2017/main/h2020-wp1617-health\\_en.pdf](https://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-health_en.pdf).
- European Commission. (2020b). *Work Programme 2018–2020*. Retrieved May 1, 2021, from [https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-health\\_en.pdf](https://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-health_en.pdf).
- Gaessler, F., Hall, B. H., & Harhoff, D. (2021). Should there be lower taxes on patent income? *Research Policy*, 50(1). <https://doi.org/10.1016/j.respol.2020.104129>.
- Gande, A., John, K., Nair, V. B., & Senbet, L. W. (2020). Taxes, institutions, and innovation: Theory and international evidence. *Journal of International Business Studies*, 51, 1413–1442. <https://doi-org/10.1057/s41267-020-00375-1>.

- Georghiou, L. (2008). Europe's research system must change. *Nature*, 452, 935–936  
<https://www.nature.com/articles/452935a>.
- Georghiou, L., Tataj, D., Celio, J., Gianni, S., Pavalkis, D., Vegranti, R., & Renda, A. (2018). *Mission-oriented research and innovation policy: A RISE perspective*. European Commission. <https://doi.org/10.2777/426921>.
- Guijarro-Madrid, A., Garcia, D., & Van Auken, H. (2009). Barriers to innovation among Spanish manufacturing SMEs. *Journal of Small Business Management*, 47(4), 465–488.
- Halpern, L. (2007). *Literature survey on the links between innovation, competition, competitiveness, entry & exit, firm survival and growth*. Working Paper no. 02/07, MICRO-DYN, EU Sixth Framework Programme. [http://www.se2009.eu/polopoly\\_fs/1.8460!menu/standard/file/lund\\_declaration\\_final\\_version\\_9\\_july.pdf](http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf).
- Hünermund, P., & Czarnitzki, D. (2019). Estimating the causal effect of R&D subsidies in a pan-European program. *Research Policy*, 48(1), 115–124.
- Ivus, O., Jose, M., & Sharma, R. (2021). R&D tax credit and innovation: Evidence from private firms in India. *Research Policy*, 50(1). <https://doi.org/10.1016/j.respol.2020.104128>.
- Jasiński, A. H. (2010). *Innowacyjność polskiej gospodarki w okresie transformacji. Wybrane aspekty*. Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego.
- Jasiński, A. H. (2013). *Innowacyjność w gospodarce Polski. Modele, bariery, instrumenty wsparcia*. Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego.
- Jasiński, A. H. (2014). *Innowacyjność w gospodarce Polski. Modele, bariery, instrumenty wsparcia*. Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego.
- Laliene, R., & Sakalas, A. (2014). Conceptual structure of R&D productivity assessment in public research organisations. *Economics and Management*, 19(1), 25–25.
- Lewandowska, M. S. (2012). Bariery finansowe a sprawność innowacyjna polskich przedsiębiorstw. In T. Rynarzewski & E. Mińska-Struzik (Eds.), *Znaczenie innowacji dla konkurencyjności międzynarodowej gospodarki* (pp. 350–362). Zeszyty Naukowe nr 246. Uniwersytet Ekonomiczny w Poznaniu.
- Lund Declaration. (2009). *Europe must focus on the grand challenges of our time*. Swedish EU Presidency. Retrieved August 8, 2021, from [http://www.se2009.eu/polopoly\\_fs/1.8460!menu/standard/file/lund\\_declaration\\_final\\_version\\_9\\_july.pdf](http://www.se2009.eu/polopoly_fs/1.8460!menu/standard/file/lund_declaration_final_version_9_july.pdf).
- Luukkonen, T. (2000). Additionality in EU Framework Programmes. *Research Policy*, 29(6), 711–724.
- Madeira, M. J., Carvalho, J., Moreira, J. R. M., Duarte, F. A. P., & de Sao Pedro Filho, F. (2017). Barriers to innovation and the innovative performance of Portuguese firms. *Journal of Business*, 9(1), 2–22.

- Mazzucato, M. (2013). *The Entrepreneurial State: Debunking public vs. private sector myths*. Anthem Press.
- Mazzucato, M. (2018). *Mission-oriented research & innovation in the European Union*. Technical report, Directorate-General for Research and Innovation (European Commission).
- Mazzucato, M. (2019). *Governing missions in the European Union*. Technical report, Directorate-General for Research and Innovation (European Commission).
- Mazzucato, M. (2021). *Mission Economy*. Penguin, Allen Lane-Penguin.
- Moura, D. C., Madeira, M. J., Duarte, F. A., Carvalho, J., & Kahilana, O. (2019). Absorptive capacity and cooperation evidence in innovation from public policies for innovation. *International Journal of Innovation Science*, 11(1), 2–19.
- Nelson, R. R. (1959). The simple economics of basic scientific research. *Journal of Political Economy*, 67(3), 297–306.
- OECD. (1993). *OECD core set of indicators for environmental performance reviews*. <http://www.oecd.org/env/indicators-modelling-outlooks/24993546.pdf>.
- OECD. (2005). *Governance of innovation systems: Volume 2. Case studies in innovation policy*. OECD Publishing. <https://doi.org/10.1787/9789264013452-en>.
- OECD. (2012). Tax incentives for research and development. *OECD Science Technology and Industry Outlook*. OECD Publishing.
- Posner, M. V. (1961). International trade and technical change. *Oxford Economic Papers*, 13(3), 323–341.
- Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014–2020) and repealing Decision No 1982/2006/EC. OJ L347/104.
- Soete L. (1981). *A general test of technology gap trade theory*. *Weltwirtschaftliches Archiv*, 117(4), 638–660.
- Van Leeuwen, G. & Klomp, L. (2006). On the contribution of innovation to multi-factor productivity. *Economics of Innovation and New Technologies*, 15(4/5), 367–390.
- Von Hippel, E., DeMonaco, H. J., & de Jong, J. P. J. (2014). *Market failure in the diffusion of clinician-developed innovations: The case of off-label drug discoveries*. <https://doi.org/10.1093/scipol/scw042>.
- Watkins, T. & Paff, L. A. (2009). Absorptive capacity and R&D tax policy: Are in-house and external contract R&D substitutes or complements? *Small Business Economics*, 33(2), 207–227.
- Weresa, M. A. (2014). *Polityka innowacyjna*. PWN.

# Bank Density, Population Density, and Economic Deprivation across the United States: Implications for Public Health Outcomes

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## Abstract

Because limited financial access has been shown to be associated with adverse public health outcomes in the United States, modeling this access and identifying geographic areas where it is deficient is essential. Recent research on the locations of bank branches has identified thresholds below which a given area can be considered to be a “banking desert.” Thus far, most analyses of the country as a whole have tended to focus on minimum distances from geographic areas to the nearest bank, while a recent density-based analysis focused only on the city of Chicago. As such, there is not yet a nationwide study of bank densities for the entire United States. This study calculates banks per square mile for US Census tracts over ten different ranges of population density. One main finding is that bank density is sensitive to the measurement radius used (for example, density in urban areas can be calculated as the number of banks within two miles, while some rural areas require a 20-mile radius). This study then compiles a set of lower 5- and 10-percent thresholds that might be used to identify “banking deserts” in various urban, suburban, and rural areas; these largely conform to the findings of previous analyses. Finally, adjusting for population density using regression residuals, this chapter examines whether an index of economic deprivation is significantly higher in the five percent of “desert” tracts than in the remaining 95 percent. The differences are largest – and highly significant – in the densest tracts in large urban areas.

## Keywords

Banking deserts – bank locations – statistical methods – United States – public health

## 1 Introduction

Although the use of online and mobile banking has increased markedly in recent years, a case can be made that “bank branches matter,” particularly for older or lower-income residents with limited mobility or technological fluency. A recent report by the Federal Reserve’s Board of Governors (2019) notes that more than half of rural counties lost banks between 2012 and 2017, and that residents face difficulties adjusting to these changes. Likewise, the Woodstock Institute (2018) notes the challenges faced by older residents in the Chicago area.

Geographic areas with relatively little financial access – so-called “banking deserts” – might instead be served by alternative (and sometimes predatory) financial service providers. Even when traditional banks are utilized, residents of areas with few banks often pay higher interest rates for limited credit (Ergungor, 2010; Nguyen, 2019). This is usually explained by a lack of information among lenders who do not understand the communities in which they are lending, or to high monitoring costs due to increased distance between borrowers and lenders (Degryse & Ongena, 2005).

In addition, “banking deserts” have been linked to social effects such as crime (Kubrin et al., 2011) or adverse public health outcomes (Eisenberg-Guyot et al., 2018). In particular, this latter study finds that being unbanked or relying on “fringe” loans are associated with higher propensities of having poor or fair health. In the United States in particular, poor financial and physical health are related; money issues can cause a person to experience high levels of stress, or an expensive hospital visit might bankrupt a patient with poor or no health insurance. Since this insurance is often provided as part of an employment compensation package, there is a strong connection between individual income and access to healthcare. The connection between financial and physical well-being, and especially the directions of causality, are worthy of future investigation.

It is important to note that the concept of “banking deserts” appears to be uniquely American – and, as is shown below, is often most evident in large central-city areas. One reason why is due to urban structure: while city centers outside the United States often constitute prime real estate, this country’s central cities (near to, but outside, the central business district) are often relatively low-income, with property values rising in the suburbs. Urban density gradients and income gradients often follow different paths in US cities compared to elsewhere. But, since poverty is concentrated in these areas, residents lack access to financial services; limited automobile access and reliance on underfunded public transportation might matter more than physical proximity to a bank branch, even if it is only a few miles away.

Second, many Americans on the edge of the formal economy rely heavily on cash payments, and often do not have personal bank accounts. In contrast, access to payment technology is often more universal in other parts of the world, and in some cases, innovations in mobile payment systems have helped foster financial inclusion among low-income communities. US residents (and especially those without citizenship status) might rely more heavily on “non-bank financial institutions” that cash third-party checks for a large fee. Others might heavily leverage personal networks or relationships with store owners (Puchalski, 2016).

While a focus here is on the US banking system and differences in access across density ranges, an additional issue involves the relative access of banks versus other types of service providers. While there is ample literature on “retail deserts” as well as areas with limited access to food and other essentials, more research needs to be done analyzing whether banks represent a high-need service (akin to healthy food) or are less commonly used (such as a department store). This would give insight regarding minimum distances and travel costs in “banking deserts.” In addition, banks, grocery stores, and department stores are often located near one another, due to zoning laws or suburban development patterns, a particular neighborhood might be a “desert” for all types of service simultaneously. This “clustering” likely drives the findings presented here, but is left to future research. As they stand, these results highlight the presence – and significance – of US central cities with high degrees of economic deprivation and limited bank access.

This study proceeds as follows: Section 2 outlines important literature regarding “banking deserts” and their implications. Section 3 describes methodology. Section 4 presents the results, and Section 5 concludes.

## 2 Literature Review

Previous literature on “banking deserts” use geospatial and/or statistical methods to identify areas where bank access is limited. This can be in absolute terms (no banks at all within a certain area), or relative (such as the percentage of tracts with the least access). Once such areas are identified, the causes of such phenomena (such as income or racial determinants), or the effects (such as increased crime or disorder) can be analyzed.

Much of the literature that finds gaps in bank service provision – the so-called “spatial void” hypothesis noted by Smith et al. (2008) – focuses on the payday loan operators and other “fringe banking” providers that seek to exploit these gaps and offer limited services at much higher costs to the consumer. Brennan et al. (2011), for example, find that poor neighborhoods in Winnipeg have been



overserved by these non-bank financial institutions and underserved by banks and credit unions. Fowler et al. (2014), on the other hand, find no evidence of any “spatial void” in their study of US counties. Racial disparities are an important covariate with the lack of banking services (Wheatley, 2010; Cover et al., 2011) as are income and socioeconomic variables such as housing tenure (Hegerty, 2016; Dunham et al., 2018).

Using a distance-based measure of “banking deserts,” Kashian et al. (2018) examine more than 60,000 Census tracts from 2009 to 2015, controlling for population density by regressing the distance from each centroid to its nearest bank and examining the residuals for urban, rural, and suburban areas separately. They find that poverty is negatively related to bank proximity only in urban areas; this relationship is insignificant in suburban tracts and positive in rural ones.

Most recently, Hegerty (2020) conducts an analysis of bank locations in Chicago, focusing on bank counts within one and two miles of each block-group centroid. He finds “banking deserts” in roughly nine percent of the city, and estimates that these areas contain roughly 0.4 banks per square mile. These block groups are shown to both be poorer and to have fewer white residents than the city as a whole, and particularly in comparison to neighborhoods with large shares of bank branches. But the “rule of thumb” implied in the paper most likely only applies to large cities, so further empirical work could find bank densities for other locations.

Is it possible to refine this definition to create a nationally applicable threshold (or set of thresholds), and how might these cutoffs differ in large cities, smaller cities, and rural areas? Kashian et al. (2018) consider the lowest 5 percent of residuals from a regression on population density (their measure of “adjusted” bank density) and find cutoffs of 1.56 miles for urban areas, 4.28 miles for suburban areas, and 12.54 miles for rural areas. Assuming that this implies one bank on the edge of each circle with the given radii, this converts to 0.41 banks per square mile only for urban areas; the corresponding suburban and rural values are 0.05 and 0.006, respectively. If banks were uniformly distributed in rural areas, this latter value would imply only two banks in a 10-mile radius, or less than eight within a 20-mile radius.

Noting that the relationship between bank and population densities appears to be nonlinear, the current study controls for population density by performing separate regressions over 10 different density ranges. Adjusted bank densities are highly correlated with the unadjusted densities, so the latter are the primary focus here. Comparing these results with those of Hegerty (2020), the 80th and 90th percentiles – in which most Chicago tracts are located – are found to have bottom 5 and 10 percent thresholds that match both the earlier block-group-level analysis and a tract-level re-estimation conducted here. Many of the most



rural areas have no banks even within 20 miles, but many rural and suburban areas have density thresholds in line with the results of Kashian et al. (2018). Comparing bank densities with the tract-level economic deprivation index of Hegerty (2019), deprivation is shown to have significantly higher in the 5 percent of tracts with the lowest bank densities than in the remaining 95 percent, but that these differences are largest at higher population densities.

### 3 Methodology

Bank data are taken from the FDIC's Summary of Deposits database; they were current as of June 30, 2019. These provided data contained 87,931 data points with both XY coordinate data and address data in the lower 48 states and the District of Columbia. These data points, which were able to be plotted in Geographic Information Systems software, comprise more than 99.9 percent of the original dataset. To maintain a single method of geocoding, no attempt was made to add the additional bank locations to the database. In addition, while Hegerty (2020) notes that FDIC latitude and longitude data contain various inaccuracies – and some were found in the current study – these were taken as is, since they constituted a small percentage of the total and did not appear to be non-randomly distributed.

These points are plotted against the 71,593 census tracts in 48 states plus DC. These tracts are used for two reasons. First, their centroids serve as the basis for buffers of different radii, within which bank densities are calculated. Second, these densities are compared against an index of economic deprivation proposed by Hegerty (2019), which uses US Census data (2015 ACS 5-year estimates) to combine five socioeconomic variables into a single measure.

In this study, bank densities are calculated as the number of bank locations per square mile, within the given radii from each tract centroid. For example, a tract with 20 banks in a 2-mile radius (which has an area of 12.57 square miles) would have 1.59 banks per 1 square mile. If, as the radius increases, the number of nearby banks changes at a rate different from the circle's area, this density could increase or decrease. It is therefore possible to look for some sort of "optimal" radius for future analyses, as well as to use different measures for rural and urban areas. While densities are calculated at quarter-mile increments from 0.25 to 20.00 miles, the primary measures of analysis are the 2-, 5-, 10-, and 20-mile radii.

To control for different types of urban, suburban, and rural areas, this paper examines and controls for population density. After plotting bank density versus (log) population density and finding a distinct nonlinear relationship, a procedure similar to that of Kashian et al. (2018) is applied, which uses regression

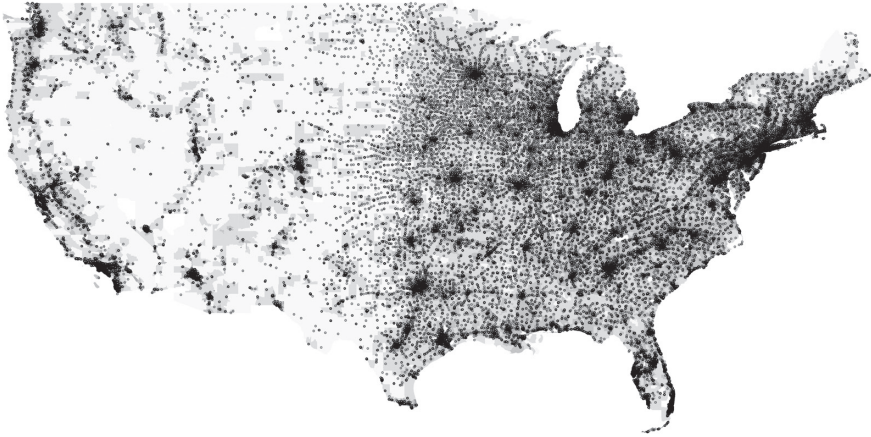


FIGURE 7.1 Bank locations (2019) and population density for US census tracts  
 Note: choropleth map of population density with natural breaks:  
 Light = low density; black = higher  
 SOURCE: CENSUS DATA, 2015 AMERICAN COMMUNITY SURVEY 5-YEAR  
 ESTIMATES AND FDIC SUMMARY OF DEPOSITS DATABASE

residuals as a measure of adjusted bank density. Log population densities are split into 10 equal segments (with unequal numbers of tracts, however) and separate OLS regressions are performed for each. The resulting residuals serve as a measure of “adjusted” bank density that can be used to measure relationships with a number of socioeconomic variables. For both the adjusted and the unadjusted bank densities, this paper focuses on the 5 and 10 percent thresholds, within each decile, using the four major measurement radii.

Finally, economic deprivation is compared in these low-density “banking deserts” against deprivation in the remaining tracts. Mean deprivation in the bottom 5 percent and top 95 percent of tracts within each population density decile are calculated and tested for significant differences using standard t-tests. Overall, the differences are largest and most significant in more “urban” tracts, generally at the 70th percentile of log population density or higher.

#### 4 Results

Figure 7.1 shows that, as expected, banks are clustered in urban areas. In the sparsely populated Western states, there are relatively few banks, even in tracts with higher population densities. Most likely, many areas will have zero banks per square mile, even within a large radius, but tracts with higher population densities and no nearby banks are more likely to be considered to be “banking deserts,” since these values are lower than expected.

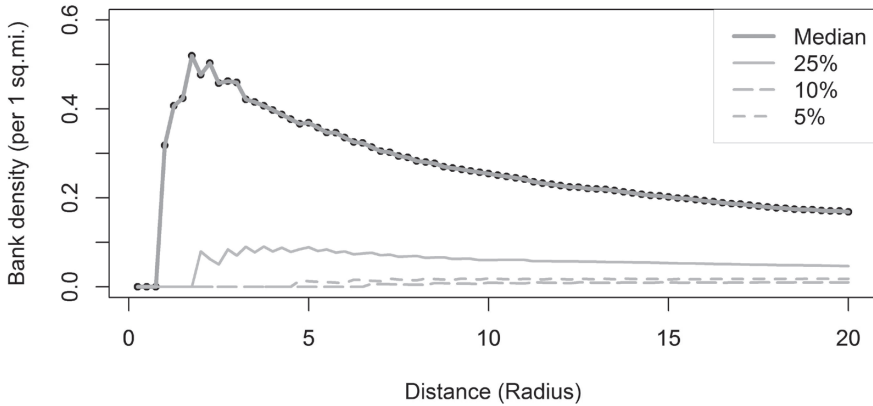


FIGURE 7.2 Bank density quantiles at different measurement radii (in miles)  
SOURCE: AUTHOR'S ELABORATION

Figure 7.2 shows how the choice of measurement radius affects the calculation of bank density. The highest median bank density is calculated when a radius of around 2 miles is applied – the average from 1.75 to 2.25 miles is almost exactly 0.500. This density declines as the measurement radius increases; most likely, the resulting circles exceed the size of nearby urbanized areas, so as the radius increases, the rate of new banks falling within the buffer is less than the increase in total area. The 5 and 10 percent quantiles stabilize for radii larger than 5 miles, however.

Table 7.1 presents summary statistics for this sample of (unadjusted) banking densities at the major radii used for this study, as well as for the index of economic deprivation. Since the median exceeds the mean in all cases, the data are skewed right.

Figure 7.3 plots bank densities (at 2 miles) against log population density; this relationship is nonlinear even when various additional transformations (not shown here) are applied. The highest decile (100th percentile) of log population density is typically composed of tracts in New York City, and the lowest (10th percentile) contains tracts in states such as Idaho and Wyoming. For comparison purposes, Chicago tracts are depicted in grey; these are typically located in the 80th and 90th percentile ranges. Table 7.2 presents statistics on the relative size, population, area, and population density of each decile. The 70th and 80th percentiles (7th and 8th deciles) contain the largest shares of tracts and population in a very small land area. The 40th to 60th percentiles are relatively less dense and might represent more small-town or “suburban” areas. Since these segments are density-, not geographically-based, they might also represent residential parts of a major city. This study, however, does not

TABLE 7.1 Summary statistics for bank densities and deprivation index

	1-Mile	2-Mile	5-Mile	10-Mile	20-Mile	Deprivation
Min.	0.00	0.00	0.00	0.00	0.00	-2.43
1Q	0.00	0.08	0.09	0.06	0.05	-1.26
Median	0.32	0.48	0.37	0.25	0.17	-0.45
Mean	1.10	0.94	0.72	0.54	0.35	-0.04
3Q	1.27	1.11	0.83	0.64	0.42	0.77
Max.	84.99	34.85	12.22	5.81	2.62	11.55
Area	3.14	12.57	78.54	314.16	1256.64	

Values calculated per 1 square mile  
 Areas of circles with given radii are presented in square miles

### 2-Mile Radius

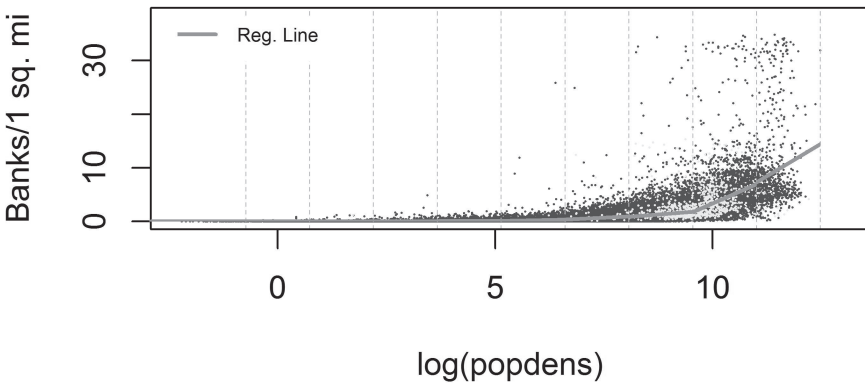


FIGURE 7.3 Bank density versus population density (2-mile measurement radius)  
 Notes:  
 Vertical lines: separators between density ranges; OLS regressions conducted for 10 separate groups  
 Grey line: OLS regression lines within each segment  
 Grey dots: tracts located in the city of Chicago  
 SOURCE: AUTHOR'S ELABORATION

focus on specific locations. In fact, as is shown for Chicago, one city's component tracts might fall across multiple density segments.

Table 7.3 shows the distributions of bank densities within each segment, as well as for the entire sample. Many tracts have zero banks per square mile; while this is especially true for the 2- and 5-mile radii, it also applies for the

TABLE 7.2 Population, area, and population density by tract group

Decile ↓	Size	Cumulative %			Log(popdens)		exp(Min)	exp(Max)
		Size	Area	Pop	Min	Max		
All	71584							
10	68	0.1	6.77	0.02	-10.00	-0.74	0.0	0.5
20	368	0.6	26.48	0.25	-0.74	0.73	0.5	2.1
30	1396	2.6	51.89	1.44	0.73	2.20	2.1	9.0
40	4867	9.4	78.19	6.72	2.20	3.67	9.0	39.2
50	8234	20.9	93.43	18.18	3.67	5.14	39.2	170.0
60	9310	33.9	97.60	32.00	5.14	6.60	170.0	738.0
70	19243	60.7	99.37	59.51	6.60	8.07	738.0	3203.5
80	22561	92.3	99.97	91.86	8.07	9.54	3203.5	13904.9
90	4772	98.9	100.00	98.59	9.54	11.01	13904.9	60355.1
100	765	100	100	99.99	11.01	12.48	60355.1	261973.9

least-dense deciles when a 20-mile radius is applied. A two-mile measurement radius, therefore, might be useful for a city such as Chicago, but it fails to find even a single bank in tracts at the 60th log population density percentile and below. The same can be said for the 5-mile radius (with a large share of zero-density tracts at the 50th percentile and below). The 10- and 20-mile radius see the same effect for the 30th and 20th percentiles, respectively.

Clearly, the choice of distance range matters among urban, suburban, and rural areas when calculating bank densities. Population density also affects the thresholds that can be used when defining “banking deserts.” In Table 7.3, the 5 and 10 percent quantile values are shown to differ across population density deciles. Chicago’s range (the 80th and 90th percentiles) match the findings of Hegerty (2020), who indirectly calculated a density of roughly 0.4 banks per square mile, using 1- and 2-mile radii, for the bottom nine percent of tracts. These findings are also confirmed for the 781 tracts in the city of Chicago, which are presented in Table 7.4, particularly when a 1-mile radius is applied. For more suburban ranges, using a 20-mile measurement radius, these quantiles fall in a range from 0.005 to 0.015 banks per square mile (which translates to between roughly 6 and 20 banks within this very large circle), and also aligns with the results of Kashian et al. (2018).

TABLE 7.3 Bank density at lower quantiles within density deciles and at different radii

Decile ↓	2-Mile			5-Mile			10-Mile			20-Mile		
	%Zero	5%	10%	%Zero	5%	10%	%Zero	5%	10%	%Zero	5%	10%
All	24.3	0	0	8.8	0	0.013	1.8	0.010	0.019	0.4	0.010	0.018
10	95.6	0	0	79.4	0	0	66.2	0	0	45.6	0	0
20	92.9	0	0	79.6	0	0	61.1	0	0	27.2	0	0
30	90.3	0	0	69.9	0	0	35.6	0	0	7.2	0	0.001
40	88.0	0	0	53.3	0	0	8.6	0	0.003	0.4	0.004	0.006
50	76.6	0	0	25.6	0	0	1.0	0.006	0.010	0	0.010	0.014
60	41.2	0	0	2.7	0.013	0.025	0.1	0.016	0.022	0	0.011	0.018
70	5.9	0	0.080	0.1	0.076	0.115	0	0.035	0.057	0	0.021	0.034
80	0.7	0.239	0.318	0	0.191	0.280	0	0.095	0.150	0	0.047	0.072
90	0	0.557	0.796	0	0.573	0.789	0	0.400	0.605	0	0.220	0.347
100	0	2.467	3.501	0	2.422	3.002	0	1.360	2.019	0	0.573	1.028

Unadjusted values = banks per 1 square mile within the given radius from block-group centroids.  
 %Zero = percentage of tracts with no banks within a given radius.

TABLE 7.4 Lower quantile bank densities for tracts located in Chicago (N = 781)

Radius (mi.)	1%	5%	10%
1	0	0.318	0.637
2	0.382	0.716	0.875
5	0.545	0.764	0.955
10	0.632	0.907	1.044
20	0.813	0.903	0.963

Table 7.5 summarizes the thresholds for the lowest bank densities in each of four density categories. The lowest threshold in urban areas is double the threshold for “less urban” areas with population densities below 3,200 per square mile. The lowest 5 percent of rural tracts have even lower bank densities. Converted into the number of banks within a given radius, these figures show (for example) that to find nine banks, one might need a circle with a 2-mile radius in an “urban” area; five miles in a suburban area, and 20 miles in a rural area. These numbers can serve as a basis when assessing whether specific neighborhoods or areas can be classified as such a “desert.”

TABLE 7.5 Summary for “banking desert” thresholds for selected population densities

Type	Percentile	Banks/mi <sup>2</sup>	#Banks in Radius (Radius)
Urban	80–90	0.24–0.80	3–10 (2mi)
Less Urban	60–70	0.013–0.115	2–9 (5mi)
Rural	40–50	0.004–0.14	5–17 (20mi)
Very Rural	<=30	0	0 (20mi)

Derived from 5 and 10 percent quantiles in Table 7.3.

The relationship between population density and bank density becomes more pronounced as the former variable increases. This is shown via the slope coefficients from a bivariate OLS regressions, within each decile. Depicted visually in Figure 7.3 for the 2-mile radius, they are generally significant at the 40th percentile or greater regardless of the measurement radius. For larger cities, we expect that even the harshest “desert” is expected to have at least a few banks nearby.

Table 7.6 shows large correlations between the adjusted and unadjusted bank-density measures, with the highest Spearman coefficients found around the 70th population-density percentile. Because they will have very few zero values at any radius, while at the same time differentiating between an area with no bank access within a populated area and a similar area in a sparsely populated one, the adjusted bank density measures are preferred when examining associations with other socioeconomic variables.

These adjusted values are used to compare differences in socioeconomic deprivation between “banking deserts” and non-deserts. Depicted graphically in Figure 7.4, the gaps between the bottom 5 percent of tracts and the remaining 95 percent are largest at the 80th percentile and above. The image of a socioeconomically deprived neighborhood with limited banking access, therefore, might hold mainly for large cities as Chicago. The t-tests in Table 7.6 show that, while small, these differences in mean deprivation scores for most tracts and density deciles are indeed significant. While differences are only significant for the 70th percentile and above within a 2-mile radius, they are significant for the 30th percentile and above when larger radii are used. Overall, areas with relatively few banks have significantly higher levels of economic deprivation than do non-deserts, but both groups’ levels – as well as the differences between them – are only large in highly urban areas.

TABLE 7.6 Statistics for regression errors and “bank deserts” at different radii

Decile	2-mile		5-mile		10-mile		20-mile	
	Cor	T-Test	Cor	T-Test	Cor	T-Test	Cor	T-Test
All	0.610	<b>16.742</b>	0.917	<b>24.449</b>	0.984	<b>32.475</b>	0.908	<b>34.068</b>
10	0.356	-0.467	0.706	-0.977	0.673	-0.977	0.771	-0.977
20	0.444	-0.118	0.619	-1.818	0.609	-0.938	0.421	1.208
30	0.514	1.840	0.809	<b>2.923</b>	0.917	<b>4.252</b>	0.824	<b>5.035</b>
40	0.563	0.630	0.896	<b>2.263</b>	0.824	<b>5.794</b>	0.801	<b>10.311</b>
50	0.741	-2.637	0.808	<b>2.369</b>	0.814	<b>10.797</b>	0.867	<b>10.665</b>
60	0.853	-2.311	0.829	<b>8.596</b>	0.904	<b>13.747</b>	0.941	<b>12.88</b>
70	0.915	<b>8.089</b>	0.923	<b>13.846</b>	0.941	<b>17.482</b>	0.956	<b>16.852</b>
80	0.919	<b>19.288</b>	0.875	<b>19.102</b>	0.880	<b>23.005</b>	0.885	<b>25.499</b>
90	0.764	<b>10.775</b>	0.747	<b>9.428</b>	0.820	<b>6.607</b>	0.889	<b>6.130</b>
100	0.917	<b>3.546</b>	0.984	<b>3.316</b>	0.908	<b>2.457</b>	0.610	<b>2.884</b>

Notes:

Cor = Spearman correlation between unadjusted bank density and adjusted bank density (regression errors of bank density on log population density).

T-Test: the difference in means between the bottom 5 percent of the regression errors (within each range) and the errors for the remaining 95 percent of Census tracts.

Bold = significantly positive at 5 percent.

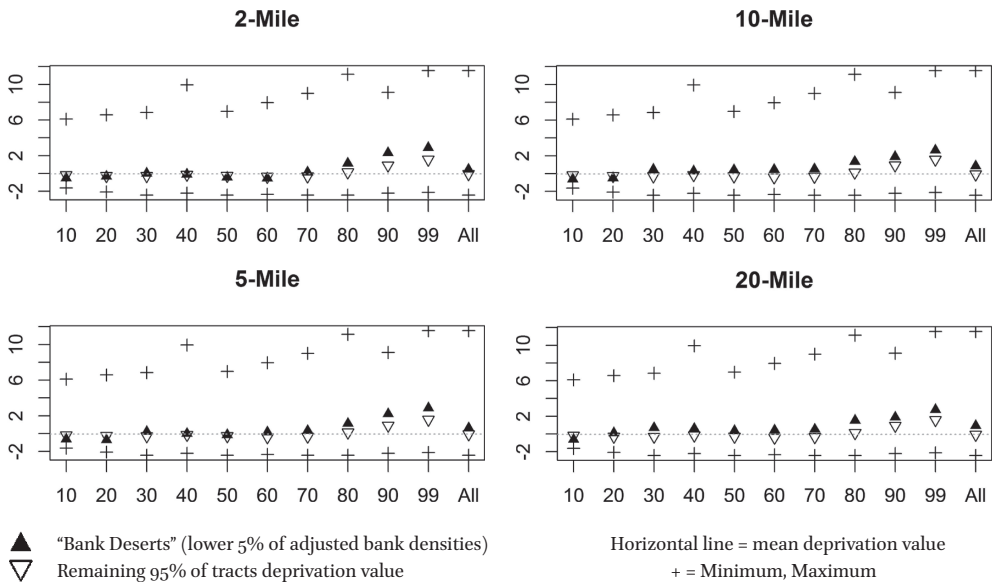


FIGURE 7.4 Mean deprivation values, “bank desert” vs. non-desert block groups

SOURCE: AUTHOR’S ELABORATION



## 5 Conclusion

While “banking deserts” are often examined by researchers and advocates who wish to increase communities’ access to financial services and limit the reach of high-interest alternative providers, little has been done to provide an exact definition of such an area. Combining the approaches of a recent distance-based analysis and a city-level density-based approach, this study calculates bank densities (number of branches per square mile) for Census tracts across the lower 48 states and the District of Columbia. Because banks’ service areas often exceed tract boundaries, these densities are calculated using a variety of measurement radii for each tract and centroid. Calculated densities, however, are sensitive to the choice of radii – a choice of two miles gives the highest median density nationwide and works well for large cities, while larger radii of 5, 10, or 20 miles work well in less-dense areas.

Bank density is compared against population density, but because the relationship is nonlinear, comparisons are made within ten deciles based on log population density. Linear regression for each segment suggests that this relationship is strongest for the highest-density, most urban, tracts. Regression analysis is also used to create an “adjusted” bank density measure, which controls for population density within each decile.

In line with the work of Kashian et al. (2018) and Hegerty (2020), this study defines thresholds to define “banking deserts” and which are based on the lowest 5 and 10 percent of unadjusted banking densities within each decile. These correspond to roughly 0.24 to 0.80 banks per square mile in highly urban tracts, 0.013 to 0.115 banks per square mile in less-urban tracts, and 0.004 to 0.14 banks per square mile in many rural tracts. These thresholds can be used to measure and compare bank access in communities across the country.

Further analysis, using the tract-level measure of Hegerty (2019), compares socioeconomic deprivation in the bottom five percent of tracts, as measured for adjusted bank density, with the remaining 95 percent. While most deciles’ differences are significant, particularly when radii of five miles are larger are applied, deprivation scores are highest and group differences are largest in the densest tracts. This suggests that more suburban and rural “banking deserts” might not face the same hardships as do their urban counterparts. This finding, which nonetheless is in line with the results mentioned above, requires further investigation.

The results presented here have clear implications for public health, especially in large US cities. Areas defined as “banking deserts” have limited financial access, which, as noted by Eisenberg-Guyot et al. (2018) above, is associated with lowered self-reported health status. The specific mechanism through which this occurs would be a worthy future study. In the near term, community

leaders and organizations could more effectively target their resources to these known areas of the city.

Three specific targets stand out as being in particular need of these resources. First, large US cities (particularly with population densities in the range of 5,000 to 10,000 per square mile) are shown here to have unique limitations in terms of financial access. This group of cities include some of the poorest urban centers in the United States, such as Buffalo, Cleveland, Detroit, Milwaukee, and St. Louis; these are also plagued by health issues such as high infant and maternal mortality rates and shortened life expectancies. A city-level approach could concentrate on areas in the density ranges shown to have the highest population densities and density levels.

Secondly, such an approach could be focused on dense, high-deprivation areas of cities nationwide, regardless of overall population or city-level population density. Even a wealthy area might have neighborhoods with high deprivation scores and limited financial access; likely, public health outcomes are worse in these areas as well. Concentrating investment in the local level might improve all three indicators in neighborhoods that are often ignored.

The third target involves investigating the nexus between these three indicators, particularly in terms of the direction(s) of causation. If financial health indeed helps improve physical health, then strengthening community ties to the banking system may directly lead to improved public health outcomes and reduced deprivation. Specific channels may include lower stress levels and improved mental health among residents, as well as access to loans for neighborhood improvement or even increased ability to pay for healthcare treatments. As a more indirect channel, if bank access is a proxy for community investment and neighborhood cohesion, then encouraging these connections will help the vitality of neighborhoods across the country. Even if causation primarily runs in the other direction – where unhealthy neighborhoods are considered not to be profitable locations for bank branches – helping to improve financial access might result in a greater degree of overall investment in highly deprived neighborhoods.

These findings point to four additional research directions. First, the impact of bank branch closings can be assessed by incorporating additional years into a study. While FDIC data go back as far as 1994, the quality of their geographic information are limited, and a large percentage of address locations would need to be geocoded by the researcher. Carefully ensuring the comparability of data over time would allow for an analysis of which socioeconomic variables are most closely related to these closings. Second, a finer breakdown of density ranges, whether in terms of more groups, varying thresholds, or a more even distribution of tracts within groups, might also be useful. Third, incorporating geography – especially including place-level information for cities and

suburbs – might also enhance the results. Finally, additional socioeconomic variables, including racial makeup, can be included in a multivariate model. The current results, however, provide an interesting look into how exactly one can define a “banking desert.”

## References

- Board of Governors of the Federal Reserve System. (2019). Perspectives from Main Street: Bank Branch Access in Rural Communities. Washington, DC.
- Brennan, M., McGregor, M., & Buckland, J. (2011). The changing structure of inner-city retail banking: Examining bank branch and payday loan outlet locations in Winnipeg, 1980–2009. *Canadian Journal of Urban Research*, 20(1), 1–32.
- Cover, J., Spring, A. F., & Garshick, R. (2011). Minorities on the margins? The spatial organization of fringe banking services. *Journal of Urban Affairs*, 33(3), 317–344.
- Degryse, H., & Ongena, S. (2005). Distance, lending relationships, and competition. *Journal of Finance*, 60(1), 231–266.
- Dunham, I. M., Foster, A., Graves, S., & Masucci, M. (2018). Navigating the dual financial service system: Neighborhood-level predictors of access to brick-and-mortar financial services. *The California Geographer*, 57.
- Eisenberg-Guyot, J., Firth, C., Klawitter, M., & Hajat, A. (2018). From payday loans to pawnshops: fringe banking, the unbanked, and health. *Health Affairs*, 37(3), 429–437.
- Ergungor, O. E. (2010). Bank branch presence and access to credit in low- to moderate-income neighborhoods. *Journal of Money, Credit and Banking*, 42(7), 1321–1349.
- Fowler, C. S., Cover, J. K., & Kleit, R. G. (2014). The geography of fringe banking. *Journal of Regional Science*, 54(4), 688–710.
- Hegerty, S. W. (2016). Commercial bank locations and “banking deserts”: A statistical analysis of Milwaukee and Buffalo. *Annals of Regional Science*, 56, 253–271.
- Hegerty, S. W. (2019). A Comparison of tract-level, nationwide indices of economic deprivation. *Economics Bulletin*, 39(1), 256–263.
- Hegerty, S. W. (2020) “Banking Deserts,” Bank Branch Losses, and Neighborhood Socioeconomic Characteristics in the City of Chicago: A Spatial and Statistical Analysis, *The Professional Geographer*, 72(2), 194–205, DOI: 10.1080/00330124.2019.1676801.
- Kashian, R., Tao, R., & Drago, R. (2018). Bank deserts in the USA and the Great Recession: Geography and demographics. *Journal of Economic Studies*, 45(4), 691–709.
- Kubrin, C., Squires, G. D., Graves, S. M., & Ousey, G. (2011). Does fringe banking exacerbate neighborhood crime rates? Investigating the social ecology of payday lending. *Criminology and Public Policy*, 10, 437–466.

- Nguyen, H.-L. Q. (2019). Are credit markets still local? Evidence from bank branch closings. *American Economic Journal: Applied Economics*, 11(2), 1–32.
- Puchalski, V. A. (2019). Credit at the corner store: An analysis of resource exchange among Detroit-Area urban poor. *Sociological Forum*, 31(4), 1040–1062.
- Smith, T. E., Smith, M. M., & Wackes, J. (2008). Alternative financial service providers and the spatial void hypothesis. *Regional Science and Urban Economics*, 38, 205–227.
- Wheatley, W. P. (2010). Economic and regional determinants of the location of payday lenders and banking institutions in Mississippi: Reconsidering the role of race and other factors in firm location. *The Review of Regional Studies*, 40(1), 53–69.
- Woodstock Institute. (2019). Digitally divided: Older adult banking vulnerabilities in the Chicago region. <https://woodstockinst.org/>.



**PART 3**

*Pharmaceutical Industry: Innovation,  
Trade, and Company Performance*





# Healthcare Systems and Pharmaceutical Industry in Emerging and Developed Economies: China and Poland versus the US and the EU

*Arkadiusz Michał Kowalski*

## Abstract

The chapter focuses on the development of healthcare and pharmaceutical industry analyzed from the perspective of the innovation divide in the world economy, as there are traditionally countries with developed national innovation systems, playing the role of technology leaders, and those with developing innovation systems, acting as innovation followers. However, together with significant structural changes taking place in the world economy, we observe a gradual shift of high-technology industries, such as the pharmaceutical industry, to emerging economies, among which China is making a considerable progress in innovation performance. The objective of this research is to measure the development of healthcare and pharmaceutical industry in economies traditionally playing the role of technological followers, that is, China and Poland, and economies positioned as innovation leaders, that is, the EU and the USA. According to the results, the development of the healthcare sector in emerging economies, in particular China, is positively associated with economic growth, and innovations in the pharmaceutical industry are critical to the present and future advances in healthcare.

## Keywords

innovation divide – high-technology industries – pharmaceuticals – healthcare – biotechnology – clusters

## 1 Introduction

The pharmaceutical industry is classified as high-technology industry, which is a science-based sector that manufactures products while performing



above-average levels of R&D. Development of the pharmaceutical industry in a country requires high innovation capability. Hence, the question arises if emerging economies such as China or Poland have enough potential to develop this type of innovative sector. Historically, the majority of innovations were generated in developed countries. Thus, the sources of economic advantages for the Triad economies – the USA, Western Europe and Japan – throughout the last decades have been variables such as knowledge and innovation, as these countries have played the roles of technology leaders in the global economy and they specialized in medium-high and high-technology industries, such as pharmaceuticals. At the same time, the developing countries have drawn on cheap resources as primary source of their economic advantage, which has resulted in specialization in labor-intensive industries. While traditionally research and development (R&D)-led technological progress was concentrated in developed countries, nowadays we are witnessing the emergence of innovation hubs in developing economies. Two countries from the latter group are analyzed in this chapter, China and Poland, and their healthcare systems and pharmaceutical industries are contrasted and compared with countries positioned as innovation leaders, that is, the EU and the USA.

Nowadays, when societies are facing so-called Grand Challenges connected, for example, with the ageing of society and civilization diseases, and the problems of the COVID-19 pandemic, a special role in people's well-being and nations' economic development is played by healthcare systems and the development of innovations in pharmaceutical sectors. Traditionally, pharmaceutical innovation has been organized in a linear fashion. This paradigm has lost its meaning over the last two decades as a result of growing expenses, increased competition, new scientific advances, and demanding users. The linear model is inadequate to accommodate these new actors. This provides the rationale to discuss, in addition to the analysis of different indicators related to healthcare systems and the development of the pharmaceutical industry, the role of clusters in this sector. In particular, China's pharmaceutical sector has grown significantly in terms of breadth and volume of manufacturing, which was accompanied by the creation and development of local pharmaceutical and biotechnological clusters.

## 2 Healthcare System Characteristics and Investments

The pharmaceutical industry plays a critical role in the development of the healthcare systems. Another crucial factor is related to health expenditure,

which has a significant impact on people's well-being and on the economic growth of countries (Fogel, 2004) and is strongly and positively associated with economic growth in both developed and developing nations (Lopreite & Zhu, 2020). However, comparing health expenditures in different economies is difficult since each country has its own set of political, economic, and social characteristics that influence its expenditures. Healthcare systems feature a range of insurance organizational structures and regulatory frameworks, as well as payment mechanisms for hospitals and physicians. Moreover, the relationship between expenditure on healthcare goods and services and total spending in the economy fluctuate over time as a result of variances in the growth of health spending compared to overall economic growth (OECD/WHO, 2020).

One of the crucial factors affecting healthcare capacity in different countries may be attributed to the level of health expenditure as a percentage of GDP (e.g., Khan, 2020; Ray & Linden, 2020; Wang et al., 2021). Long-term comparisons of current health expenditures as a share in GDP and per capita in China and Poland, in relation to the United States and the European Union, are presented in Table 8.1.

The highest level of current health expenditure as a share in GDP, as well as per capita, takes place in the USA, followed by the European Union analyzed as a whole. It confirms that wealthy countries tend to spend more per person on healthcare and related expenses than lower-income countries. However, a strong increase can be observed in health expenditure in all the analyzed

TABLE 8.1 Current health expenditure, 2000–2018

Country	2000	2005	2010	2015	2016	2017	2018	%Δ(2000–2018)
	% of GDP							
China	4.47	4.14	4.21	4.89	4.98	5.15	5.35	19.7
Poland	5.30	5.81	6.42	6.40	6.54	6.56	6.33	19.4
United States	12.54	14.61	16.35	16.71	17.05	17.00	16.89	34.7
European Union	8.43	9.07	9.88	9.94	9.93	9.88	9.85	16.8
	per capita, PPP (current international \$)							
China	129	208	381	702	759	838	935	625.6%
Poland	564	807	1353	1717	1851	1979	2015	257.0%
United States	1814	2388	3178	3695	3869	4075	4206	131.8%
European Union	4564	6455	7930	9491	9878	10210	10624	132.8%

SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM WORLD BANK (2021)

economies. The reasons include so-called grand challenges, which are connected with a collection of activities fostering innovation to address critical global health and development issues, including the ageing of society or lifestyle diseases. With this respect, Lopreite and Zhu (2020) observed a strong correlation between the ageing index and life expectancy in the United States and China, as well as between health spending per capita and GDP per capita, whereas China's ageing population induces a relatively strong correlation between health spending per capita and GDP per capita.

Health expenditures include all costs associated with preparing for and maintaining an individual's health, and they are conceptually distinct in each country. In general, they may be divided into two categories: public and private. Public health expenditures include social security contributions, taxes on the private and public sectors, and borrowings and subventions from foreign governments. Private health expenditures, on the other hand, include private health insurance, out-of-pocket health costs, and so on (Poullier, Hernandez, & Kawabata, 2003). The general tendency in the world economy is that with the exception of few countries, public expenditure largely replaces private spending, especially in high-income countries (Vrijburg & Hernández-Peña, 2020). A comparison of domestic general government health expenditure as % of GDP in all the analyzed economies is presented in Table 8.2.

Domestic general government health expenditure as % of GDP is at the highest level in the European Union, but the fastest increase during analyzed period took place in China. From the organizational point of view, an increase in current health expenditure in China in the last decade can be attributed to the fact that this country formally initiated the New Health System Reform (NHSR) in 2009. The goal was to provide inexpensive healthcare to all Chinese citizens through the establishment of a basic universal provision of safe, effective, convenient, and low-cost services (Zhao et al. 2020). This comprehensive reform increased health insurance coverage significantly, with 95.7 percent of the Chinese population covered by three major social health insurance:

TABLE 8.2 Domestic general government health expenditure (% of GDP)

Country	2000	2005	2010	2015	2016	2017	2018	%Δ (2000–2018)
China	0.98	1.36	2.18	2.94	2.89	2.92	3.02	207.1%
Poland	3.61	3.98	4.58	4.44	4.50	4.52	4.50	24.5%
United States	6.31	6.74	7.35	7.36	7.36	7.34	7.34	16.2%
European Union	5.54	6.63	7.95	8.47	8.59	8.55	8.51	53.6%

SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM WORLD BANK (2021)

the Urban Employee-Based Medical Insurance (UEBMI) program, the Urban Resident-Based Medical Insurance (URBMI) program and the New Rural Cooperative Medical Scheme (NCMS) (Meng et al., 2015). However, the growing proportion of the population aged 65 or over has resulted in a global increase in health spending as a result of increased demand for medical and long-term care services, posing a growing threat to the sustainability of national public budgets. This tendency is particularly pronounced in China, which has seen both economic growth and population ageing increase over the last four decades (Loprete & Zhu, 2020).

The open research question is if public or private health expenditures have the most important effect on health outcomes. According to the findings of Crémieux et al. (2005), private health expenditures have a greater impact on health outcomes than public health expenditures in countries with mixed healthcare systems and traditional sickness insurance. Additionally, Berger and Messer (2002) indicate that the impact of public health spending is less than that of private health expenditures, or that these expenditures are insignificant in general. Moreover, public health expenditure has been hypothesized to crowd-out private healthcare expenditure (Ying, Chang 2020). On the other hand, according to some other studies (e.g., Novignon et al., 2012; Rad et al., 2013; Akinci, 2014), the effect of public health expenditure is greater than the effect of private health expenditure, which is due to the private sector's lower responsibility for healthcare in comparison to the public sector. The comparison of domestic private health expenditure as % of current health expenditure in the analyzed countries is presented in Figure 8.1.

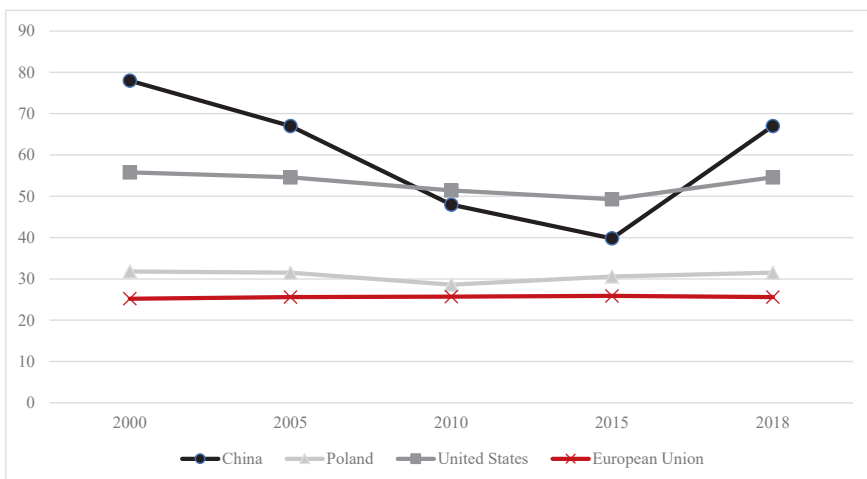


FIGURE 8.1 Domestic private health expenditure (% of current health expenditure)  
SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM WORLD BANK (2021)

The European Union, including Poland, has a lower share of domestic private health expenditure as % of current health expenditure in comparison with China and the USA. In China, individuals are increasingly responsible for the majority of healthcare financing as part of China's economic change. This reflects a rapid transition from a centrally-planned economy to a market-oriented one with fast economic growth and a *laissez-faire* approach to healthcare that emphasizes self-reliance and out-of-pocket payment (Song et al., 2020). The United States has a healthcare system that largely consists of private providers and private insurance, but as healthcare has become a larger part of the economy, a higher share of healthcare funding has been provided by government (it increased by 16% in 2000–2018). It confirms the findings of Nunn, Parsons, and Shambaugh (2020), who note that some of the rise is due to increased spending as per capita income increases, while some is due to innovations that provide new healthcare services and products. They also document that the United States pays higher prices than most countries because of a lack of competition and high administrative costs. This is connected to the phenomenon of Baumol's cost disease, which describes how sectors with relatively low productivity growth, such as healthcare, tend to experience rising costs (Baumol & Bowen, 1965; Baumol et al., 2012).

Advocates for pro-government policies stress market failings in the health sector and place a premium on equity. Proponents of free markets believe that the government also makes important mistakes and that market forces continue to work to improve efficiency in the health sector. However, the public sector does not cover all household health expenditures unconditionally on a global scale. If households are unable to meet the public standards for covering some of their health expenditures, they will be forced to cover the costs by themselves. This may result in financial difficulties for people due to their payment capacity being limited, not only in low-income countries, but also in high-income countries (Xu et al., 2003). Such a situation means a financial catastrophe due to health expenditure, which is referred to as catastrophic health expenditure. The risk of catastrophic expenditure for surgical care in the analyzed countries is presented in Table 8.3. Catastrophic expenditure is defined in the World Bank database as direct out-of-pocket payments for surgical and anesthesia care exceeding 10% of total income.

The lowest proportion of people at risk of catastrophic expenditure for surgical care is found in Poland, followed by the United States and the EU. On the other hand, it is at the highest level in China, which is in line with the findings of Boz et al. (2020) that catastrophic health expenditures are more likely to occur in developing countries where health insurance coverage is insufficient, and in low-income regions. On the other hand, when high-income countries

TABLE 8.3 Risk of catastrophic expenditure for surgical care (% of people at risk)

Country	2005	2010	2015	2016	2017	2018	%Δ (2000–2018)
China	62.5	34.3	13.3	12.3	11.2	9.5	–85%
Poland	2.1	0.6	0.3	0.2	0.1	0.1	–95%
United States	0.9	0.7	0.7	0.7	0.6	0.6	–33%
European Union	3.1	2.8	3.0	2.7	2.5	2.4	–24%

SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM WORLD BANK (2021)

such as the US are considered, the cost of surgical treatments increases due to innovation and the advanced technology used. Technological progress and new treatment procedures that involve advanced technology result in improved health outcomes but also increase expenses. Thus, these countries face the possibility of catastrophic health expenditure. Moreover, Boz et al. (2020) showed that increased public health spending as a percentage of total health spending minimizes the likelihood of catastrophic health expenditure for surgical procedures.

### 3 Development of the Pharmaceutical Industry, with Focus on Clusters

The nature of the pharmaceutical industry is such that the key driver for its growth is innovation (Schuhmacher 2013). Innovations in pharmaceuticals are critical to the present and future advances in healthcare, and their role has been increasing during the COVID-19 pandemic. The pharmaceutical industry is classified among high-technology industries in the OECD classification (Hatzichronoglou, 1997) of manufacturing industries based on technology, according to their R&D intensity defined as direct R&D expenditures as a percentage of production (gross output), calculated after converting countries' R&D expenditures and production using GDP PPPs.

The pharmaceutical industry has a long history of innovation. It has maintained a tight and successful two-way relationship with academic research institutes in chemistry, pharmacology, life sciences, and medicine. The succession of technologies generated ripples rather than waves of creative destruction because leading firms were adaptable enough to the demands of new regimes and even prospered as a result of them. A flourishing and very

TABLE 8.4 Export market share: pharmaceutical industry

	2000	2005	2010	2015	2016	2017	2018	2019	ppΔ (2000–2019)
Poland	0.15	0.20	0.45	0.58	0.54	0.76	0.60	0.57	0.38
United States	12.13	9.22	9.03	9.64	9.28	8.47	8.13	8.67	-0.55
China	1.76	1.43	2.22	2.54	2.52	2.66	2.76	2.62	1.19

SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM OECD (2021)

profitable business was founded, with many of its innovations becoming household names for over a century and others having a profound effect on our society's nature, structure, and morality. In fact, there is no other industry with a comparable impact (Achilladelis & Antonakis, 2001).

Foreign trade can be a substantial stimulant for innovation, as it promotes increased effectiveness through the development of a country's specialization in those fields where the country is relatively more efficient. Additionally, participation in foreign markets indicates the necessity of contending with international competition, which serves as a motivator for searching for and implementing R&D outcomes. Thus, foreign commerce can influence an economy's innovation system by encouraging the imitation or adaption of foreign ideas or by stimulating the development of wholly new solutions (Weresa, 2014). A comparison of the export market share of the pharmaceutical industry in the analyzed economies is presented in Table 8.4.

The highest level of export market share of the pharmaceutical industry is reported in the USA, which confirms the US economy's advancement in this sector, and innovativeness of the American economy. However, in a dynamic perspective, the US export market share of the pharmaceutical industry is slightly diminishing, whereas we can observe an increase of Chinese economy in this respect. Poland is lagging behind the analyzed countries and it does not exhibit specialization in the pharmaceutical industry. This confirms the general specialization of the Polish economy in the low-and medium-low technology industries, with a minority of companies being involved in high-technology sectors, e.g., as presented by Kowalski and Weresa (2014).

One of the most important drivers of technological advancement of the pharmaceutical industry is biotechnology, which is intensively used to develop new products, new processes, methods and services and to improve existing ones. Biotechnology has led to a considerable progress in the healthcare sector by driving the development of drugs that are optimized for therapeutic

TABLE 8.5 Number of patents in the biotechnology sector – applications filed under the PCT (priority year) per billion GDP (constant prices, constant exchange rates, OECD base year)

Country	2005	2010	2015	2016	2017	%Δ (2005–2017)
China	28	54	76	95	117	324.46%
Poland	29	56	69	51	38	30.00%
European Union	180	195	184	170	166	-7.53%
United States	305	274	303	304	304	-0.42%

SOURCE: AUTHOR'S CALCULATIONS BASED ON DATA EXTRACTED FROM OECD (2021)

efficacy. A comparison of the number of patents in the biotechnology sector between the analyzed countries is presented in Table 8.5.

The leading position in the number of patents per billion GDP in the biotechnology sector is taken by the US, followed by the EU, but in the dynamic perspective these two economies experience a decline in this indicator. On the other hand, China is making very fast progress, with a 324% increase in the number of patents per billion GDP in the biotechnology sector.

China's pharmaceutical sector has grown significantly in terms of breadth and volume of manufacturing. Nonetheless, it was just one type of progression to commercialization of imitation drugs, whereas basic research remained severely inadequate. There were few new medications and little investment in creative research and development. China's pharmaceutical sector is very undeveloped compared to the United States and Japan (Wang et al., 2009). Hence, the Chinese government takes actions aiming to transition the industry away from simple pharmaceutical production and toward pharmaceutical innovation (Prevezer, 2008). It also takes measures to enhance the pharmaceutical industry's competitiveness through the establishment of clusters. The rationale for this drew on successful policy actions supporting export-oriented production clusters, which has compelled the Chinese government to replicate the cluster-based strategy by attracting enterprises in high-technology sectors to special economic zones or science and innovation parks. However, Hanel et al. (2020) question if cluster policies exploiting economies of agglomeration and scale in labor-intensive industries are likely to be as successful in high-technology sectors such as biotechnology or the pharmaceutical industry because of the need for skilled employees. While the Chinese central government has implemented a series of policies to promote the development of a pharmaceutical cluster, local governments have also implemented policies to promote the development of local pharmaceutical industry clusters, taking



into account their own interests as well as local resources and the environment (Conle & Taube, 2010). Additionally, the promotion of cross-border cluster cooperation takes place under the Belt and Road Initiative, which is also used by China to promote more balanced regional development by opening up the western region in the country. This initiative also includes the Silk Road Cities Network concept, presenting the idea of a system of cities clustered along the New Silk Road into a network complex. This network will also include Polish cities, including three important players in the Belt and Road Initiative framework: Warsaw, Łódź, and Kutno (Kowalski, 2019).

As a result of diverse growth paths, resource constraints, and historical factors, the pharmaceutical sector in China has distinct regional features. The distribution of resource endowment has largely provided the background for the creation and growth of Chinese pharmaceutical clusters (Conle & Taube, 2010). Because the traditional Chinese medicine business is significantly more developed in China than the other pharmaceutical industries, clusters in this area were the first to be established. They are mostly concentrated in areas with an abundance of Chinese herb resources, such as the Changbai Mountains and the Sichuan Province. Chemical medicine production clusters are mostly developed in the Jiangsu and Zhejiang Provinces, which are renowned for their abundance of chemical raw materials and production capacity. Cluster formation also results in organizational and network changes through mergers and acquisitions and collaboration. Apart from the natural resources, the Chinese government played a critical role in the establishment, development, and distribution of pharmaceutical clusters (Yu et al., 2014). Different strategies are implemented by local governments in China to encourage the establishment of clusters and to improve the long-term competitiveness of their economies. In the creation and growth of clusters, the role of the local government is beneficial as long as the local government implements appropriate policies and pays more attention to the actual needs of clusters (Prevezer, 2008). As shown by Yu et al. (2014), China's local strategy for pharmaceutical clusters serves two objectives:

- 1) to maximize the use of local resources, such as natural resources, infrastructural facilities, and industrial base, in order to effectively create industrial clusters that will support industrial emergence and improve industrial competitiveness. While the particular local strategy may vary depending on the type of cluster resources, encouraging internal dynamics within clusters is usually stressed as a means of improving long-term competitiveness.
- 2) to complement the relationships and interactions between innovation actors. The similarities in local governments' policies promoting

collaboration between innovation actors demonstrate that local governments in China have made significant efforts to not only establish industrial clusters but also to strengthen industrial competitiveness by enhancing interactions between firms within industrial clusters and between clusters and the outside world, which is particularly important during the economic downturn.

As shown by Kowalski (2020), the key to development success in China lies in closing the technological gap by importing existing technology (e.g., through foreign direct investments, which are concentrated mostly in eastern provinces, and associated technology transfer), and strengthening internal capabilities to utilize and improve on those technologies (e.g., through science, technology, and innovation policy, investment in research and development, and emergence of innovative regional clusters). The first factor was of particular importance for the development of the pharmaceutical industry in China and related transfer of technology. Pharmaceuticals were one of the first sectors in China to open up to foreign investors. Direct foreign investment has poured into the pharmaceutical industry since 1980, when the first Sino-foreign pharmaceutical joint venture was established. Since then, China has attracted huge amounts of inward FDIs as a result of both spontaneous market dynamics and place-based preferential policies at the regional level. However, there are significant differences in FDI geographical distribution among territories in the Chinese market (Li et al., 2017). Nevertheless, foreign investment and advanced technologies have fueled the modernization and expansion of China's domestic pharmaceutical companies. They transfer to China modern production lines and production technologies, cutting-edge management skills and strategies, as well as more opportunities for information exchange and training.

#### 4 Conclusions

Special attention is put in this chapter on healthcare systems and development of innovations in pharmaceutical sectors. Healthcare expenditure is a factor significantly effecting people's well-being and nations' economic development. The analysis here finds the highest level of current health expenditure as a share in GDP, as well as per capita, in the USA, followed by the European Union. It indicates that rich nations spend more on healthcare and associated costs per person than low-income ones. However, we find a significant rise in health spending across all the economies studied. One reason is what are known as great challenges, which refer to a set of actions aimed at encouraging innovation in order to solve major global health and development problems,

such as population aging or lifestyle illnesses. This is especially concerning in China, where fast economic development together with an aging population results in a high correlation between health expenditure and GDP per capita.

Different studies investigate the effectiveness of public and private health expenditures, with different research outcomes. When compared to China and the United States, the European Union, including Poland, has a lower share of domestic private health spending as a percentage of total health spending. In China, as a result of the country's economic transformation from a centrally planned to a market-oriented economy, a *laissez-faire* approach to healthcare that promotes self-reliance and out-of-pocket expenditure dominates. The United States has a healthcare system that is mostly composed of private providers and private insurance, but as healthcare has grown in importance as a sector of the economy, the government has contributed a greater amount of healthcare funding. Some of the growth of healthcare expenditure results from increased spending as per capita income increases, while some is attributable to innovations that supply new healthcare services and products.

Innovations in the pharmaceutical industry are critical to the present and future advances in healthcare. The pharmaceutical sector has a long history of innovation, with close and productive collaboration with university research institutes in chemistry, pharmacology, life sciences, and medicine. The largest export market share of the pharmaceutical industry is in the United States, indicating that economy's advancement in this area and the innovativeness of the American economy. However, from a dynamic standpoint, the US pharmaceutical industry's export market share is slightly declining, whilst the Chinese economy is dynamically growing in this respect. Similarly, China is making very fast progress in the number of patents per billion GDP in the biotechnology sector, despite the leading position taken by the US. An important role in developing the Chinese innovation potential in the pharmaceutical and biotechnological sector is played by the local strategy for the development of clusters in these industries. It aims to maximize the utilization of available local resources and to complement the relationships and interactions between innovative actors. China has successfully leveraged financial resources produced by low- and medium-tech industries, and the strength of its massive internal market to build its high-technology industries, including pharmaceuticals.

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## References

- Achilladelis, B., & Antonakis, N. (2001). The dynamics of technological innovation: The case of the pharmaceutical industry. *Research policy*, 30(4), 535–588.
- Akinci, F., Hamidi, S., Suvankulov, F., & Akhmedjonov, A. (2014). Examining the impact of health care expenditures on health outcomes in the Middle East and N. Africa. *Journal of Health Care Finance*, 41(1).
- Baumol, W., De Ferranti, D., Malach, M., Pablos-Méndez, A., Tabish, H., & Wu, L. (2012). *The cost disease: Why computers get cheaper and health care doesn't*. Yale University Press.
- Baumöl, W. J., & Bowen, W. G. (1965). On the performing arts: the anatomy of their economic problems. *The American Economic Review*, 55(1/2), 495–502.
- Berger, M. C., & Messer, J. (2002). Public financing of health expenditures, insurance, and health outcomes. *Applied Economics*, 34(17), 2105–2113.
- Boz, C., Mete, A. H., & Aslan, Ö. (2020). Determinants of catastrophic health expenditure for surgical care: panel regression model. *Indian Journal of Surgery*, 1–6.
- Conlé, M., & Taube, M. (2010). Regional specialization in China's biopharmaceutical industry. *Chinese Management Studies*, 4(4), 339–359.
- Crémieux, P. Y., Meilleur, M. C., Ouellette, P., Petit, P., Zelder, M., & Potvin, K. (2005). Public and private pharmaceutical spending as determinants of health outcomes in Canada. *Health Economics*, 14(2), 107–116.
- Fogel, R. W. (2004). Health, nutrition, and economic growth. *Economic Development and Cultural Change*, 52(3), 643–658.
- Hanel, P., He, J., Fu, J., Reid, S., & Niosi, J. E. (2020). A romance of the three kingdoms: Biotechnology clusters in Beijing, Shanghai, and Guangdong Province, China. In M. Khosrow-Pour (Ed.) *Disruptive technology: Concepts, methodologies, tools, and applications* (pp. 1241–1289). IGI Global. DOI:10.4018/978-1-5225-9273-0.ch061.
- Hatzichronoglou, T. (1997). Revision of the high-technology sector and product classification. *OECD Science, Technology and Industry Working Papers*, 1997/02.
- Khan, J. R., Awan, N., Islam, M., & Muurlink, O. (2020). Healthcare capacity, health expenditure, and civil society as predictors of COVID-19 case fatalities: A global analysis. *Frontiers in Public Health*, 8(347).
- Kowalski A. M. (2019). The perspectives on interregional cluster cooperation under BRI Frame, in: J. Shi & G. Heiduk (Eds), *Opportunities and challenges. Sustainability of China-EU relations in a changing world* (pp. 189–209). China Social Sciences Press.
- Kowalski, A. M. (2020). Dynamics and factors of innovation gap between the European Union and China. *Journal of the Knowledge Economy*, 1–16. DOI:10.1007/s13132-020-00699-1.
- Kowalski, A. M., & Weresa, M. A. (2014). Innovation in the medical devices industry – case study of RAVIMED Ltd., Poland. In J. Shorley & J. Williams (Eds), *SLIM Ideas-to-market case studies* (pp. 49–72). Manchester Metropolitan University.

- Li, S., Angelino, A., Yin, H., & Spigarelli, F. (2017). Determinants of FDI localization in China: A county-level analysis for the pharmaceutical industry. *International Journal of Environmental Research and Public Health*, 14(9), 985.
- Lopreite, M., Zhu, Z. (2020). The effects of ageing population on health expenditure and economic growth in China: A Bayesian-VAR approach. *Social Science & Medicine*, 265, 113513.
- Meng, Q., Fang, H., Liu, X., Yuan, B., & Xu, J. (2015). Consolidating the social health insurance schemes in China: towards an equitable and efficient health system. *The Lancet*, 386(10002), 1484–1492.
- Novignon, J., Olakojo, S. A., & Nonvignon, J. (2012). The effects of public and private health care expenditure on health status in sub-Saharan Africa: new evidence from panel data analysis. *Health Economics Review*, 2(1), 1–8.
- Nunn, R., Parsons, J., & Shambaugh, J. (2020). *A dozen facts about the economics of the US health-care system. The Hamilton Project*, Brookings Institution.
- OECD/WHO. (2020). *Health at a glance: Asia/Pacific 2020 measuring progress towards universal health coverage. Measuring progress towards universal health coverage*. OECD Publishing.
- OECD. (2021). *OECD.Stat [Database]*. Retrieved August 7, 2021, from <https://stats.oecd.org/>.
- Poullier, J. P., Hernandez, P., Kawabata, K. (2003). National health accounts: concepts, data sources and methodology. In: Ch. J. L. Murray & D. B. Evans (Eds). *Health systems performance assessment: debates, Methods and empiricism* (pp. 185–193). World Health Organization.
- Prevezer, M. (2008). Technology policies in generating biotechnology clusters: A comparison of China and the US. *European Planning Studies*, 16(3), 359–374.
- Rad, E. H., Vahedi, S., Teimourzad, A., Esmaeilzadeh, F., Hadian, M., & Pour, A. T. (2013). Comparison of the effects of public and private health expenditures on the health status: a panel data analysis in Eastern Mediterranean countries. *International Journal of Health Policy and Management*, 1(2), 163.
- Ray, D., & Linden, M. (2020). Health expenditure, longevity, and child mortality: dynamic panel data approach with global data. *International Journal of Health Economics and Management*, 20(1), 99–119.
- Schuhmacher, A., Germann, P. G., Trill, H., & Gassmann, O. (2013). Models for open innovation in the pharmaceutical industry. *Drug Discovery Today*, 18(23–24), 1133–1137.
- Song, Z., Zhu, Y., Zou, H., Fu, H., & Yip, W. (2020). A tale of transition: Trends of catastrophic health expenditure and impoverishment in urban China, 1986–2009. *Health Systems & Reform*, 6(1), e1836731.
- Wang, K., Hong, J., Marinova, D., & Zhu, L. (2009). Evolution and governance of the biotechnology and pharmaceutical industry of China. *Mathematics and Computers in Simulation*, 79(9), 2947–2956.

- Wang, S. C., Chang, N. W., Chen, W. J., Yang, M. H., Chen, S. L., & Sung, W. W. (2021). Trends of testicular cancer mortality-to-incidence ratios in relation to health expenditure: An ecological study of 54 countries. *International Journal of Environmental Research and Public Health*, 18(4), 1546.
- Weresa, M. A. (2014). Concept of national innovation system and international competitiveness – a theoretical approach. In M. A. Weresa (Ed.). *Innovation, human capital and trade competitiveness* (pp. 81–103). Springer.
- World Bank. (2021) *World Development Indicators* [Database, last updated July 30, 2021]. Retrieved August 4, 2021, from <https://databank.worldbank.org/source/world-development-indicators>.
- Vrijburg, K. L., & Hernández-Peña, P. (2020). Global spending on health: Weathering the storm 2020. World Health Organization. <https://www.who.int/publications/i/item/9789240017788>.
- Xu, K., Evans, D. B., Kawabata, K., Zeramdini, R., Klavus, J., & Murray, C. J. (2003). Household catastrophic health expenditure: a multicountry analysis. *The Lancet*, 362(9378), 11117.
- Ying, Y. H., & Chang, K. (2020). The effect of National Health Insurance on private health expenditure in Taiwan: Crowd in or crowd out?. *Journal of the Asia Pacific Economy*, 25(2), 371–385.
- Yu, Y., Ma, Z., Hu, H., & Wang, Y. (2014). Local government policies and pharmaceutical clusters in China. *Journal of Science and Technology Policy Management*, 5(1), 41–58.
- Zhao, Y., Oldenburg, B., Mahal, A., Lin, Y., Tang, S., & Liu, X. (2020). Trends and socio-economic disparities in catastrophic health expenditure and health impoverishment in China: 2010 to 2016. *Tropical Medicine & International Health*, 25(2), 236–247.

# Export Patterns in Medical Products in the Times of the Covid-19 Pandemic: Focus on Pharmaceuticals

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## Abstract

The aim of this chapter is to identify a pattern of international trade in medical products in the context of tackling the COVID-19 pandemic. Medical products are grouped according to classifications of the World Trade Organization into four categories: pharmaceuticals, medical equipment, medical consumables, and personal protective products. This study focuses on the international trade of pharmaceuticals, which represents over a half of the total value of medical product trade. The United States, Germany, and Switzerland are key players regarding exports of medical products; however, the leaders differ in exports of the four medical product groups. Switzerland holds a predominant position in exports of pharmaceuticals, the US leads in exports of both medical equipment and medical consumables, while China is the world's top exporter of personal protective products, occupying the 7th place in total exports of medical products. The analysis of Revealed Comparative Advantage (RCA) indices showed that high trade values do not necessarily translate into specialization in trade. Switzerland and Ireland are the world's leaders in terms of relative trade specialization in medical products, in particular they enjoy high comparative advantages in trade of pharmaceuticals. The US and China, although both have relative specialization in overall medical exports, do not reveal comparative advantages in trade of pharmaceuticals.

## Keywords

medical products – pharmaceuticals – international trade – revealed comparative advantages – US – Germany – China – Switzerland

## 1 Introduction

The COVID-19 pandemic has challenged health systems all over the world. The capacity of health systems to fight pandemics depends on many different

factors, such as the institutional framework and governance of health care, financing mode, access to medicines, etc. In strengthening this capacity, international trade in medical goods also has an important role to play to ensure access to medical equipment, products for prevention, testing and treatment, in particular pharmaceuticals and other related goods. The OECD analysis highlights trade interdependencies between countries proving that no country has been able to efficiently produce all the goods that are necessary for fighting the virus (OECD, 2020). As a consequence of the COVID-19 outbreak, global demand for medical products as well as international trade flows increased significantly. In 2020, imports and exports of medical goods grew by 16%, whilst before the pandemic their growth amounted to around 5% annually. The share of medical goods in world trade reached 6.6% in 2020, up from 5.3% in 2019 (WTO, 2021).

As due to the pandemic international trade in medical products gained particular attention, there is a need to identify changes in global trade patterns, including changes in trade competitiveness that occurred during the pandemic. Although there is a growing number of analyses that show current trends in international trade of medical products, they focus on trade policy responses (Evenett et al., 2021; Baccus et al., 2021) or challenges for selected regions (Vickers et al., 2020; Hakobyan & Cherif, 2021). Changes in global trade patterns of pharmaceuticals caused by the pandemic, including trade competitiveness, have not been studied in depth. This chapter aims at filling this gap by comparing international trade flows in pharmaceuticals before and during the COVID-19 pandemic. The main objective of the chapter is to investigate the shifts in export patterns and competitiveness of global players in the market of medical products, i.e., the US, Germany, Switzerland, Ireland, and China using trade indicators such as export shares, the Revealed Comparative Advantage (RCA) index and the Trade Intensity Index (TTI).

The study is structured as follows: Section 2 summarizes main findings of recent empirical literature regarding trade in medical products focusing on trade in pharmaceuticals. Section 3 describes the methodology and data used in this study. Section 4 contains the results and discussion, and Section 5 concludes.

## 2 Trade in Medical Products – a Literature Review

The pharmaceutical industry being high-growth and innovation-intensive industry is regarded as a strategic sector in many countries. Medicines produced by the pharmaceutical industry as well as international trade of drugs



are highly important for a proper functioning of healthcare systems due to its direct impact on the health of society. In the 21st century, the pharmaceutical industry has experienced important structural changes, driven by technological and institutional changes (Munos, 2009), the COVID-19 pandemic being one of such shocks that have affected all parts of the industry's value chain (Mikic et al., 2020). Due to these changes, some adjustments occurred at enterprise level followed by market structure reconfiguration, both domestically and globally. Although the majority of pharmaceutical companies are multinationals, there are still some national differences in pharmaceutical regulation that may impact international trade flows. The areas in which the regulatory framework may differ across countries include patent protection, the registration process for new medicines, national pricing and reimbursement strategies and procedures (Garattini & Padula, 2018). Furthermore, public health policies may also pursue specific objectives such as access to medicines, control of health care expenditures or support to medical innovation, which may result in some restrictions on the free movement of pharmaceuticals. The empirical literature confirms that the differences among countries regarding the regulatory framework influence the size of trade and international competitiveness of the pharmaceutical sector. Despite growing international interdependence, which has fostered the harmonization of pre-market standards in the pharmaceutical industry, various modes of state regulatory governance result in lack of convergence in post-market standards (Wiktorowicz et al., 2018). Differences in the regulatory framework between countries and their impact on trade in pharmaceutical products were proved for various countries. Mahajan (2018) studied the case of the Indian pharmaceutical industry and showed that changes in the product patent regime had an impact on the size of research and development expenditure, trade as well as revealed comparative advantages in foreign trade of drugs. A comparative assessment of pharmaceutical trade of India and China confirmed the role of governments in both countries in shaping the international competitiveness of the pharma industry. In both countries, a rapid growth of pharma exports had been noted already before the COVID-19 pandemic. In India, pharmaceutical exports have been growing at a steeply increasing pace, while China saw gradual growth. India has traditionally been oriented towards the domestic market as well as the less regulated markets of Africa, Asia, and Latin America, while in China the policy focus is placed on transforming the pharma industry from a generic drug orientation towards an innovation-driven drug production and trade (Sami, 2014). A study on US biopharmaceutical competitiveness revealed that foreign price controls inflated the US trade deficit, which appeared to be about two-thirds larger than it would have been without price differences (Ezell, 2020, p. 15).

In the case of Hungary, the mode of privatization significantly influenced further development of the pharma industry in this country, affecting the value chain paths; some parts of the value chain were moved outside the country (Antalóczy et al., 2020), which had an impact on export and import directions.

Apart from country case studies, the global perspective on trade flows and their impact also seems to be important. Globalization of pharmaceutical trade was proved to improve healthcare coverage of the Millennium Development Goals (Yuan et al., 2019). Some studies however, while admitting the positive contribution of international trade to satisfying health needs, also found the adverse impact of global trade liberalization on limiting the capacity to ensure universal health coverage (Missoni, 2013).

When it comes to empirical studies on competitiveness in trade of pharmaceutical goods, a comparative analysis of a wide set of traditional and new indices of trade competitiveness calculated for 28 developed countries for the years 2000–2012 showed that Ireland, Slovenia, and Greece relied on comparative advantage, which was based on production factor endowments, while Belgium, the US, and the Netherlands were able to create competitive advantage in trade based on R&D and innovation. Only a few studied countries, namely Germany, Switzerland, the United Kingdom, and France enjoyed both comparative and competitive advantages in the analyzed period (Mousavi et al., 2018).

Some of these trends were confirmed by Reis and Pinto (2022) for the years 2013–2015. Using a wide range of indicators, evidence on pharmaceutical value chains confirming the center-periphery relationship was provided. The centers to which the US belongs in America as well as Switzerland and Germany in Europe specialize in high-value added activities and benefit more from the participation in global value chains than other countries. Brazil, Russia, and Saudi Arabia belong to the global peripheries as they are weakly integrated into global value chains of the pharmaceutical industry. There is also a group of countries, such as China, India, Mexico, Hungary, and Poland which are large exporters of pharmaceuticals, but they build their competitiveness on low costs, which translates into low prices, having also a high content of foreign value added in their exports and deficits in charges for the use of foreign intellectual property (IP) by the pharma industry. Ireland, Israel, Singapore, Austria, Canada, Italy, and Spain are in-between these center-periphery groups, as they are strong exporters and importers of pharmaceuticals having average levels of foreign value added in their exports and enjoying surpluses in IP charges (Reis and Pinto, 2022). A study on competitiveness factors of the pharmaceutical industry used a survey conducted among participants from pharmaceutical companies to prioritize these determinants. The analysis shows that the two key

factors which matter the most for competitiveness of pharmaceutical companies are human capital and macro-level policies (Shabaninejad et al., 2014).

The COVID-19 pandemic has had a very serious impact on international trade, its volumes, as well as geographical and industry patterns. Sector-level gravity modelling based on trade data for 28 countries and their trading partners shows that sectoral characteristics such as the scale of remote work, integration into global value chains or characteristics of goods matter for the strength and direction of trade effects (Espitia et al., 2021). During the pandemic, the supply of medicines has become more important than ever; therefore, the study of short-term changes in international trade that occurred in pharmaceutical trade between 2018 and 2020 may shed some light on future trends in trade in this product group, which is highly important for public health.

### 3 Methodology and Data

This analysis uses the Harmonized System (HS) classification as a base to distinguish medical products. Products are categorized according to the specific HS 6-digit subheading codes and grouped into four categories according to the World Trade Organization (2020; 2021) classification of products that are relevant to COVID-19 prevention and treatment. These are: pharmaceuticals, medical equipment and technology, medical consumables, and personal protective products.

Export patterns will be analyzed using international competitiveness indicators, such as annual exports growth, geographical structure of exports, the Revealed Comparative Advantage (RCA) index, and the Trade Intensity Index (TTI).

The RCA index is based on the formula developed by Balassa (1965; 1979) and is commonly used to assess export potential. For an overview of the advantages and disadvantages of the index and other alternative measures of international specialization see: Hoen & Oosterhaven, 2006; Misala, 2014; Laursen, 2015). The RCA index is defined as follows:

$$RCA_{Ki} = (X_{Ki} / \Sigma X_K) / (X_{Wi} / \Sigma X_W),$$

where:

$X_{Ki}$  is exports of commodity group “i” from country “K” to the world

$\Sigma X_K$  is total exports from country “K” to the world

$X_{Wi}$  is the world’s exports of product i

$\Sigma X_W$  is the world’s total exports

- i – sector according to the abovementioned classification  
 K – studied country.

An RCA greater than 1 ( $RCA > 1$ ) indicates the existence of a revealed comparative advantage, while an RCA lower than 1 ( $RCA < 1$ ) means a revealed comparative disadvantage. The higher the value of a country's RCA for product i, the higher its export strength (specialization) in this product. The growth of this index over time shows improvement in the competitive position of a good in the world.

The RCA indices showing either the existence or lack of a revealed comparative advantage in trade were calculated for the five leading exporters for each of the four groups of medical products singled out in the WTO classification. This preliminary screening of major trends in trade of medical products is followed by an in-depth analysis of international competitiveness in trade of medical products. The RCA indices for leading world exporters of drugs are compared to determine their comparative advantages in the times of the COVID-19 pandemic.

The Trade Intensity Index (TII) is used to assess bilateral trade potential. It is calculated using the following formula:

$$T_{ij} = (x_{ij}/X_{it}) / (x_{wj}/X_{wt})$$

where:

$x_{ij}$  is the value of country exports of product i to country j

$x_{wj}$  is the world's exports of product i to country j

$X_{it}$  is the country's total exports of product i

$X_{wt}$  is the world's total exports of product i.

A value of the index higher than one ( $TII > 1$ ) indicates that a bilateral trade is larger than it could be expected, given the partner country's involvement in world trade.

The analysis covers the period of the COVID-19 pandemic, that is, the years 2019 and 2020.

## 4 Results

In 2020, the value of world exports of medical goods amounted to US\$ 1,159 billion, growing by 16% compared to previous year, that is, four times higher than in 2019. During the same period, imports of medical products grew by

16.5% (compared to the 5.2% growth a year before), reaching US\$ 1,183 billion in 2020, and as a result the share of medical products in world trade increased from 5.3% to 6.6% (WTO, 2021). Figure 9.1 compares the structure of medical exports by four main product groups in 2018 and 2020. As expected, pharmaceuticals take the highest share in total exports of medical products standing at 54% in 2018, but decreasing to 52% in 2020 due to the increase in the share of personal protective products. The remaining three categories of medical products have similar shares ranging from 13% (medical equipment) to 18% (medical consumables).

The five leading exporters include Germany, the US, Switzerland, the Netherlands, and Belgium. Among the world's top ten exporters there is only one emerging economy, namely China, which occupies the seventh place, the others being developed countries. The same ten countries are also top importers of medical goods, they are however ranked in a different order. The US occupies the first place in terms of the imports value, followed by Germany, China, Belgium, and the Netherlands (WTO, 2020). These 5 countries deliver nearly a half of the total value of all world exports of medical products. Table 9.1 illustrates the relative importance of medical goods relevant to combating COVID-19 and their subcategories in each country's total exports in 2019. In some countries, exports of medical products have a double-digit share in total exports. Switzerland and Germany took the lead in terms of the pharmaceutical export value. In both the medical equipment and medical consumable segments, the US and Germany are main sources of the world's exports, while in personal protective products the top two exporters are China and the US.

Looking at the values of medical exports from an individual country perspective, it can be noted that the relatively strongest dependency on medical export is in Ireland, where such exports constituted around 38% of the country's total exports. In Switzerland, this share was as high as 29%, while in China it was only 2%, and in the US it reached 7%.

Pharmaceuticals constituted a vast majority of medical exports in Switzerland (88% of exported medical products in 2019), Italy (75%), Belgium (74%), and Ireland (71%). In China, personal protective products are key medical exports goods constituting 49% of total medical exports in this country.

The analysis of RCA indices for top ten exporters of medical products show that high trade values do not necessarily translate into specialization in trade. Switzerland and Ireland are the world's leaders in terms of relative trade specialization in medical products, which is confirmed by the high values of RCA indices in these two countries, with Switzerland holding a predominant position in the trade of pharmaceuticals. There is only one country, namely China,

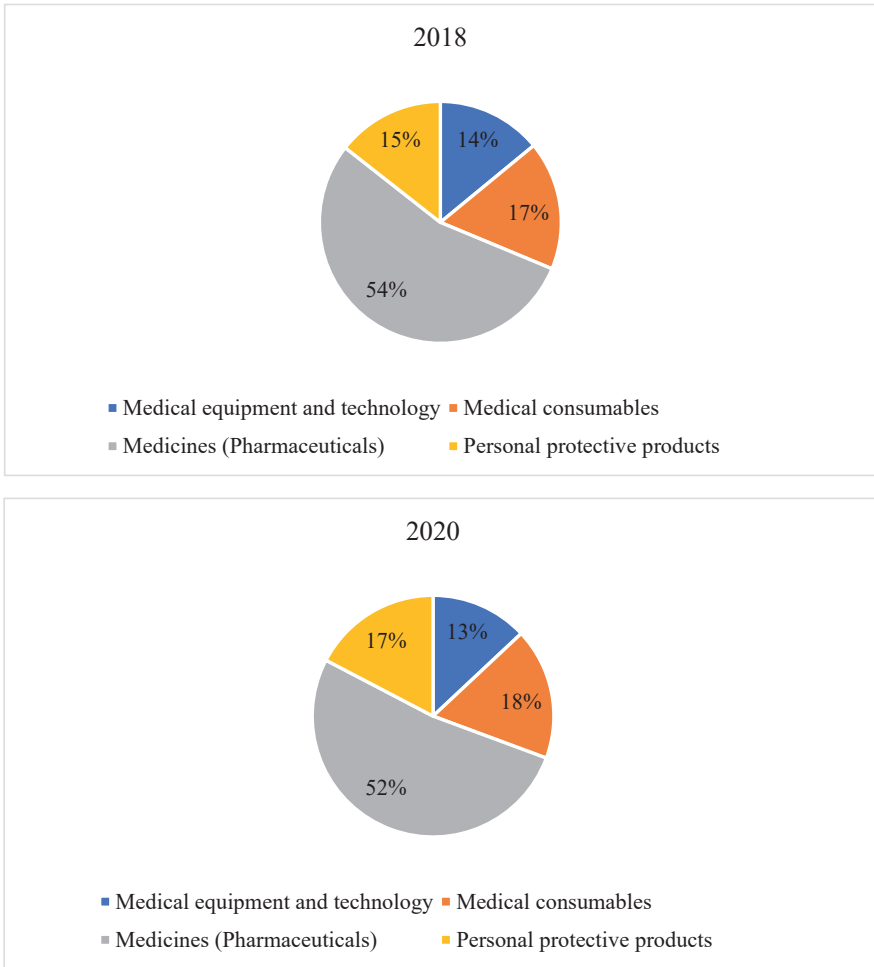


FIGURE 9.1 The structure of medical exports by four main product groups in 2018 and 2020  
 SOURCE: AUTHOR'S ELABORATION BASED ON WTO DATA (WTO, 2020; 2021)

among the world's top ten exporters of medical goods that do not enjoy comparative advantage in overall medical trade. The RCA index below one ( $RCA = 0.333$ ) indicates that medical goods are not part of China's trade specialization.

However, RCA indices calculated separately for each of the four medical product groups show that patterns of comparative advantages of the analyzed top exporters differ significantly. In trade of medical equipment, three countries from the analyzed group – France, Italy and China – do not enjoy

TABLE 9.1 Top ten exporters of medical products in 2019

	Total exports of medical products			Exports by	
	<i>Value US\$ billion</i>	<i>Share of medical products in total exports (%)</i>	<i>Share in world's medical exports (%)</i>	<i>Pharmaceuticals (US\$ billion)</i>	<i>Medical equipment (US\$ billion)</i>
World	995.8	6	100	547.69	139.41
Germany	136.2	9	14	77.63	20.43
USA	116.6	7	12	40.81	29.15
Switzerland	89.9	29	9	79.11	4.50
Netherlands	73.1	10	7	42.40	12.43
Belgium	65.8	15	7	48.69	5.26
Ireland	65.3	38	7	46.36	3.27
China	51.6	2	5	5.16	9.80
France	49.9	9	5	32.44	3.99
Italy	42.9	8	4	32.18	2.57
United Kingdom	38.2	8	4	24.45	4.20

SOURCE: AUTHOR'S ELABORATION BASED ON WTO DATA (WTO, 2020)

comparative advantages, with the two latter also not revealing relative specialization in trade of medical consumables. When it comes to personal protective products, the US, Switzerland, the Netherlands and the UK are in a relatively disadvantageous position (Table 9.2).

Trade of pharmaceuticals is relatively advantageous for top eight exporters, except China and the US. The RCA indices did not change much over the 2019–2020 period. The highest values of RCA indices are for Ireland and Switzerland (Figure 9.2), which confirms a relatively strong position of these two countries in the world market.

Having discussed the diversity of the overall pattern of trade of the world's top ten exporters of medical goods, it is worth to gain a more detailed picture looking at their bilateral trade performance with key trade partners in the medical goods segment reflected in the values of the trade intensity index. Lack of detailed data for all ten countries limits this analysis to four selected exporters and their key export markets for which data is available. The analysis covers export of medical goods from the US, Germany, Switzerland, and Ireland to their two main trade partners. The results are presented in Table 9.3.

Share in total medical exports (%)					
<i>Medical consumables (US\$ billion)</i>	<i>Personal protective products (US\$ billion)</i>	<i>Pharmaceuticals</i>	<i>Medical equipment</i>	<i>Medical consumables</i>	<i>Personal protective products</i>
169.29	139.41	55	14	17	14
20.43	17.71	57	15	15	13
33.81	12.83	35	25	29	11
4.50	1.80	88	5	5	2
13.16	5.12	58	17	18	7
7.90	3.95	74	8	12	6
13.06	2.61	71	5	20	4
11.35	25.28	10	19	22	49
6.99	6.49	65	8	14	13
3.00	5.15	75	6	7	12
5.73	3.82	64	11	15	10

TABLE 9.2 RCA index for four groups of medical goods trade of top 10 world's exporters, 2019

	<b>Medical products in total</b>	<b>Pharmaceuticals</b>	<b>Medical equipment</b>	<b>Medical consumables</b>	<b>Personal protective products</b>
Germany	1.500	1.555	1.607	1.324	1.393
USA	1.167	0.742	2.083	1.990	0.917
Switzerland	4.833	7.733	1.726	1.422	0.690
Netherlands	1.667	1.758	2.024	1.765	0.833
Belgium	2.500	3.364	1.429	1.765	1.071
Ireland	6.333	8.176	2.262	7.451	1.810
China	0.333	0.061	0.452	0.431	1.167
France	1.500	1.773	0.857	1.235	1.393
Italy	1.333	1.818	0.571	0.549	1.143
United Kingdom	1.333	1.552	1.048	1.176	0.952

SOURCE: AUTHOR'S ELABORATION BASED ON WTO DATA (WTO, 2020)



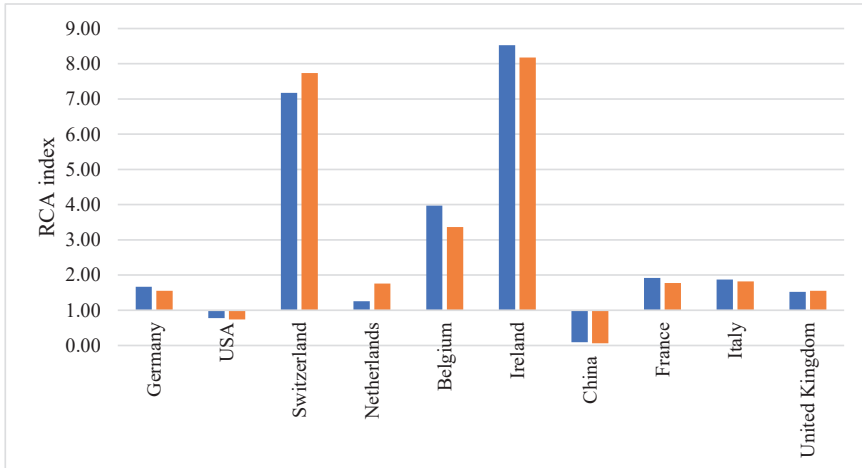


FIGURE 9.2 Revealed Comparative Advantages for trade of COVID-related pharmaceuticals: selected top exporters compared in 2019–2020  
 SOURCE: AUTHOR’S ELABORATION BASED ON UN COMTRADE (WITS, 2021) AND WTO (2021)

TABLE 9.3 Trade Intensity Index (TTI) for medical goods: selected top exporter compared, 2019

Exporting country	Partner	TTI
Germany	United States	0.848
Germany	China	1.341
United States	Germany	0.788
United States	China	1.348
Switzerland	Germany	1.020
Switzerland	United States	0.984
Ireland	United States	2.270
Ireland	Germany	0.838
China	United States	1.417

SOURCE: AUTHOR’S ELABORATION BASED ON WTO DATA (WTO, 2020)

The values of the trade intensity index calculated for bilateral trade of medical products between the United States and Germany are below one, for both trade directions: for Germany as exporter to the US and for the US exports to Germany. This shows that a bilateral trade flow of medical goods between the

US and Germany is smaller than expected taking into account the importance of both countries in world trade. Switzerland, the third largest world exporter of medical products, has quite intense trade with Germany but lower than its exporting potential with the United States. The opposite situation occurs in Ireland, where large trade connections with the United States and smaller with Germany are noted. This can be explained by huge investment of US multinationals in Ireland resulting in high intensity of intra-company trade flows. Trade intensity of the world's two key exporters of medical goods – Germany and the US – with China (the world's 7th exporter) also requires a comment. TII for both countries' exports of medical products to China is higher than one, which indicates that both countries fully use their trade potential regarding the delivery of medical products to the Chinese market.

TABLE 9.4 Trade Intensity Index for bilateral trade of pharmaceuticals: selected top medical exporters compared, 2019

Exporting country	Partner	Pharmaceuticals	Total bilateral trade
United States	Switzerland	0.882	0.699
United States	China	1.819	0.689
United States	Germany	0.841	0.557
United States	Ireland	3.401	1.205
Ireland	Switzerland	0.262	2.336
Ireland	China	0.186	0.574
Ireland	Germany	0.553	1.366
Ireland	United States	2.107	2.659
Germany	Switzerland	1.897	2.794
Germany	China	1.026	0.771
Germany	Ireland	1.004	1.313
Germany	United States	0.831	0.772
Switzerland	Germany	1.409	2.340
Switzerland	Ireland	0.310	0.741
Switzerland	United States	1.335	1.207
Switzerland	China	1.180	0.730
China	Switzerland	0.267	0.117
China	Germany	0.338	0.489
China	Ireland	0.113	0.287
China	United States	0.573	1.447

SOURCE: AUTHOR'S ELABORATION BASED ON UN COMTRADE DATA (WITS, 2021)

As far as trade intensity of pharmaceuticals is concerned, UN Comtrade data allow results of bilateral trade of the selected top exporters of medical goods to be compared with the intensity of total bilateral trade with the partner. Table 9.4 above shows the results for bilateral trade of pharmaceuticals compared to total bilateral trade for the US, Germany, Ireland, and China.

Bilateral trade of pharmaceuticals as well as total bilateral trade is very intense in both directions between the US and Ireland, between Germany and Switzerland, and between the US and Switzerland. However, among these pairs, there are only two countries that have higher pharma export intensity than total bilateral exports. This is the case with US exports of pharmaceuticals to Ireland and Swiss pharma exports to the US. There is also one important feature of the TII pattern regarding bilateral trade of pharmaceuticals. It should be noted that the US, Germany, and Switzerland have higher than expected values of the TII for their pharma exports. It might be attributed to increased exports of vaccines during the pandemic; however, this hypothesis should be further tested with the use of more detailed trade data.

## 5 Conclusion

This chapter focuses on a pattern of international trade in medical products that are used to tackle the COVID-19 pandemic. According to the World Trade Organization classification, four categories of COVID-related medical products have been distinguished: pharmaceuticals, medical equipment, medical consumables, and personal protective products. Pharmaceuticals constitute the most important group among these four, as they account for over a half of the total value of medical product trade. The major exporters of medical products are the United States, Germany, and Switzerland, but leaders differ for each of the studied groups of goods. Switzerland takes the lead in exports of pharmaceuticals, the US occupies the first place in both medical equipment and medical consumables exports, China is the most important world supplier of personal protective products. The analysis of Revealed Comparative Advantage (RCA) indices showed that high trade values do not necessarily translate into specialization in trade. Switzerland and Ireland have the highest comparative advantages in trade of pharmaceuticals. The US and China, having relative specialization in overall medical exports, do not reveal comparative advantages in trade of pharmaceuticals. The analysis of bilateral trade intensity of top five exporters of medical goods – the US, Germany, Ireland, and Switzerland, China shows huge differences among the studied countries.

In particular, the TII pattern is diverse for trade in pharmaceuticals, with high bilateral trade intensity in bilateral trade between countries that have strong linkages through multinational corporations' networks that belong to the same language group, and share similar socio-cultural heritage, for example between Ireland and the US, or between Germany and Switzerland.

These findings point to further research directions. First, it would be interesting to study the changes in trade patterns using more disaggregated trade data. Second, the role of multinational companies as drivers of bilateral trade in medical goods, including pharmaceuticals, could be another future research topic. Last, but not least, gravity models can be used to further explain bilateral trade determinants.

## References

- Antalóczy, K., Gáspár, T., & Sas, M. (2019). The specialties of the pharmaceutical value chain in Hungary. *Acta Oeconomica*, 69(S2), 41–72. DOI: 10.1556/032.2019.69.S2.3.
- Balassa, B. (1979). The changing pattern of comparative advantage in manufactured goods. *The Review of Economics and Statistics*, 61(2), 259–266. DOI: 10.2307/1924594.
- Barlow, P., van Schalkwyk, M., McKee, M., Labonté, R., & Stuckler, D. (2021). COVID-19 and the collapse of global trade: Building an effective public health response. *Lancet Planet Health* 2021; 5(2), e102–e107. DOI: [https://doi.org/10.1016/S2542-5196\(20\)30291-6](https://doi.org/10.1016/S2542-5196(20)30291-6).
- Chakraborty, P. (2020). Indian pharmaceuticals industry in global scenario: An appraisal. *Journal of Health Management*, 2(3), 424–429. DOI: 10.1177/0972063420937939.
- Espitia, A., Mattoo, A., Rocha, N., & Ruta, M. (2021). Pandemic trade: COVID-19, remote work and global value chains. *The World Economy*, 45(2), 561–589. DOI: 10.1111/twec.13117.
- Evenett, S., Fiorini, M., Fritz, J., Hoekman, B., Lukaszuk, P., Rocha, N., Ruta, M., Santi, F., & Shingal, A. (2021). Trade policy responses to the COVID-19 pandemic crisis: Evidence from a new data set. *The World Economy*, 45(2), 342–364. <https://doi.org/10.1111/twec.13119>.
- Ezell, S. (2020). *Ensuring U.S. biopharmaceutical competitiveness*. ITIF Information Technology & Innovation Foundation. Retrieved August 10, 2021, from <https://itif.org/publications/2020/07/16/ensuring-us-biopharmaceutical-competitiveness>.
- Garattini, L., & Padula, A. (2018). Competition in pharmaceuticals: more product- than price-oriented? *Eur J Health Econ*, 19, 1–4. <https://doi.org/10.1007/s10198-017-0932-4>.
- Hakobyan, S., & Cherif, R. (2021). Trade in medical goods: Challenges and a way forward for Sub-Saharan Africa. *Special Series on COVID-19*. IMF African Department.

- Retrieved August 4, 2021, from <https://www.imf.org/en/Publications/SPROLLs/covid19-special-notes#MSI>.
- Hoehn, A. R., & Oosterhaven, J. (2006). On the measurement of comparative advantage. *The Annals of Regional Science*, 40(3), 677–691. <https://doi.org/10.1007/s00168-006-0076-4>.
- Laursen, K. (2015). Revealed comparative advantage and the alternatives as measures of international specialization. *Eurasian Bus Rev*, 5, 99–115. DOI: 10.1007/s40821-015-0017-1.
- Mahajan, V. (2019). Structural changes and trade competitiveness in the Indian pharmaceutical industry in product patent regime. *International Journal of Pharmaceutical and Healthcare Marketing*, 13(1), 21–39. <https://doi.org/10.1108/IJPHM-12-2016-0066>.
- Mikic, M., Puutio, T. A., & Gallagher, J. G. (2020). Healthcare products trade and external shocks: The US-China trade war and COVID-19 pandemics, *ARTNeT Working Paper Series No. 190*, ESCAP.
- Misala, J. (2014). Theoretical grounds of the development of long-term competitive advantages in international trade. In M. A. Weresa (Ed.). *Innovation, human capital and trade competitiveness, innovation. How are they connected and why do they matter?* (pp. 3–51). Springer International Publishing. DOI 10.1007/978-3-319-02072-3\_1.
- Missoni, E. (2013). Understanding the impact of global trade liberalization on health systems pursuing universal health coverage. *Value in Health*, 16, S14–S18.
- Mousavi, S., Rasekhi, S., Golestani, M., & Imani, A. (2018). Studying international competitiveness in pharmaceutical sector in selected developed countries. *Asian Journal of Pharmaceutical and Clinical Research*, 11, 451–460.
- Munos, B. (2009). Lessons from 60 years of pharmaceutical innovation. *Nat Rev Drug Discov*, 8, 959–968.
- OECD. (2020). Trade interdependencies in COVID-19 goods. Retrieved July 31, 2021, from <https://www.oecd.org/coronavirus/policy-responses/trade-interdependencies-in-covid-19-goods-79aaa1d6/>.
- Reis, C. F., & Pinto, J. P. G. (2022). Center – periphery relationships of pharmaceutical value chains: A critical analysis based on goods and knowledge trade flows. *Review of Political Economy*, 34(1). DOI: 10.1080/09538259.2021.1882192.
- Sami, S. (2014). Fostering pharmaceutical trade in India and China: An empirical study. *Transnational Corporations Review*, 6(4), 379–391. DOI:10.5148/tncr.2014.6404.
- Shabaninejad, H., Mehralian, G., Rashidian, A., Baratimarnani, A., & Rasekh, H. R. (2014). Identifying and prioritizing industry-level competitiveness factors: Evidence from pharmaceutical market. *DARU Journal of Faculty of Pharmacy, Tehran University of Medical Sciences*, 22(1), 35. <https://doi.org/10.1186/2008-2231-22-35>.
- Wiktorowicz, M., Moscou, K., & Lexchin, J. (2018). Transnational pharma cogovernance: Emergent patterns in the jazz of pharmaceutical policy convergence. *Globalization and Health*, 14(86). <https://doi.org/10.1186/s12992-018-0402-5>.

- WITS. (2021). *UN Comtrade [Database]*. Retrieved August 31, 2021, from <https://wits.worldbank.org/>.
- WTO. (2020). Trade in medical goods in the context of tackling COVID-19. *Covid-19 Reports*, No. 2020/01, WTO. Retrieved July 28, 2021, from <https://doi.org/10.30875/5a1af59c-en>.
- WTO. (2021). Trade in medical goods in the context of tackling COVID-19: Developments in 2020. Retrieved August 15, 2021, from [https://www.wto.org/english/tratop\\_e/covid19\\_e/medical\\_goods\\_update\\_jun21\\_e.pdf](https://www.wto.org/english/tratop_e/covid19_e/medical_goods_update_jun21_e.pdf).
- Yuan, B., Li, J., & Wang, Z. (2019). Globalization of pharmaceutical trade and healthcare coverage of the Millennium Development Goals. *Journal of Pharmaceutical Health Services Research*, 11(1), 85–89. DOI:10.1111/jphs.12326.

# Pharmaceutical Companies as Portfolio Investments

*Izabela Pruchnicka-Grabias*

## Abstract

The aim of the study is to analyze pharmaceutical companies quoted on the Warsaw Stock Exchange as part of the investment portfolio in order to check whether their stocks can be used as a diversification tool for investors. Traditional and alternative performance measures are calculated to conclude that results are different for different time periods; however, in each of them it was possible to choose some companies which performed better than the benchmark WIG20TR index according to all applied performance measures. This suggests that pharmaceutical companies can be good diversifying assets for other equity investments. The study is original and unique because the literature usually offers research based on fundamental factors, such as different financial ratios calculated for pharmaceutical companies when performance is analyzed. Authors do not consider their performance on stock exchanges. However, analyzing stock market fluctuations is important because performance is not only based on financial ratios but also on investor sentiment and behavior of market speculators who often make market prices deviate from their fundamental values based on the traditional financial analysis. The considered study period starts in January 2017 and ends in June 2021. It was the maximum time span available for the analysis because some companies are quite young. The study is based on weekly data to avoid daily market fluctuations because the main assumption is that the investment period is either medium or long. The analysis may help investors and capital diversification seekers to optimize their investment decisions.

## Keywords

pharmaceutical companies – portfolio diversification – performance

## 1 Introduction

The pharmaceutical industry is concerned with a special type of risk because only about 10% of developed drugs are finally placed on the market and about 20% of them allow the breakeven point to be achieved (CMR, 2007/2008; Datamonitor, 2008; Nickisch et al., 2009). Besides, the productivity of pharmaceutical research has been decreasing over the last decades (Kannt & Wieland, 2016). Product development in this industry is often outsourced, which creates many different kinds of risk, as for example knowledge losses which result from disintegration of undertakings involved in product development (Lowman et al., 2012). Sumbramanian and Dugar (2012) also emphasize the fact of outsourcing activities connected with drug discovery to countries where costs are lower, with India or China being notable examples. Such a system requires sharing knowledge and experience and risks being used by others. Korzeniowska (2020) points out the risk of the inappropriate choice of a consulting firm whose mistakes affect the producer. However, the author also admits that outsourcing in this industry is necessary because maintaining the whole research and production operations requires a well-developed system to be in place, and employing high-paid experts is often not cost-effective. All the above factors influence the valuation of a company reflected by its stock prices.

This study is original and unique because the literature usually offers research based on different fundamental values, such as financial ratios calculated for pharmaceutical companies when performance is analyzed. Authors do not consider their performance on stock exchanges. However, it is important because it is not only based on financial ratios but also on investor sentiment and behavior of market speculators who often make market prices deviate from their fundamental values based on the traditional financial analysis.

## 2 Literature Review

The pharmaceutical industry is thought to be highly innovative and an important contributor to GDP, and therefore there are many studies on the profitability of pharmaceutical companies in different countries (e.g., Mouri, et al., 2013; Ali, 2020). Ledley et al. (2020) compare the profitability of pharmaceutical companies with other entities from the S&P index based on using their financial statements for 2000–2018 and conclude that generally the former perform better than the latter. Fenyves et al. (2019) use return on equity to check the profitability of pharmaceutical companies in Central and Eastern Europe and find out that it has increased recently. Farhan et al. (2020) focus on the board of directors as an aspect that can affect the profitability of pharmaceutical



companies alongside other factors such as financial indicators, size or age company. Barbuta-Misu (2013) shows the impact of financial leverage on the profitability of pharmaceutical companies in Romania. Lim and Rokhim (2021) find links between liquidity, sustainable growth rate and profitability measured by financial indicators such as return on equity, return on assets or earnings per share. Anghel et al. (2018) explore relationships between intellectual capital and financial performance of 24 biotech companies in 2002–2014. Basha (2014) examines the influence of crude oil prices on the financial performance of pharmaceutical companies in Jordan in 2002–2011. The paper shows a statistically significant impact of the former on the latter measured by return on assets, return on equity, or net profit margin. Farhan et al. (2019) study the relationship between liquidity and financial performance of Indian pharmaceutical companies. Nsiah and Aidoo (2015) analyze the profitability, liquidity or solvency and probability of going bankrupt of Indian companies listed on the Ghana Stock Exchange. Endri et al. (2020) analyze the financial performance of nine pharmaceutical companies from the Indonesia Stock Exchange. Like the other cited authors, they use typical financial ratios as measures of financial performance. Rehan et al. (2020) present interdependencies between the capital structure and financial performance of pharmaceutical companies in Pakistan. Mansouri and Bagheri (2015) make a ranking of pharmaceutical companies from the Tehran Stock Exchange according to their financial performance and assess them with the use of financial ratios.

Besides, the existing literature tends to focus on profitability only without comparing it to risks taken by pharmaceutical companies. The types of risks involved in pharmaceutical activity are analyzed in separate studies (Golec, Vernon, 2009; Vernon et al., 2010; Baltes et al., 2014).

This study is different in that it does not concentrate on the profitability of pharmaceutical companies themselves but treats them as portfolio investment vehicles. Thus, the perspective taken here is that of the equity investor. Although the profitability understood as financial results undoubtedly influences the profitability of direct stock investments, they can be also influenced by other factors such as technical analysis or the presence of market speculators.

### 3 The Methodology of the Study

The author analyzes pharmaceutical companies quoted on the Warsaw Stock Exchange operating in Poland which form the WIG-Leki index and compares their effectiveness with the WIG20TR index of 20 biggest companies on the same exchange.

The study period starts in January 2017 and ends in June 2021. Such a choice derives from the fact that some companies were not quoted before January 2017, and consequently a longer timeframe would not consider all the pharmaceutical companies which comprised the WIG-Leki index at the time the study was conducted. WIBOR was used as a risk-free interest rate from the end of the study period. If there were no quotations on the day concerned, the previous date was considered. The literature does not give a clear answer to the question if the risk-free interest rate should be taken from the beginning or from the end of the study period, or changed during the period (Bernando & Ledoit, 2000). WIBORs were downloaded from [www.stooq.com](http://www.stooq.com) for standard periods and interpolated linearly for the required periods. The data were divided into four study periods depending on the market trends of the WIG20 Total Return index:

- 2 January 2017–23 February 2020 – horizontal trend, the risk-free rate is a three-year WIBOR = 1.84%,
- 24 February 2020–15 March 2020 – bear market, the risk-free rate is a three-week WIBOR = 1.61%,
- 16 March 2020–13 June 2021 – bull market, the risk-free interest rate is a one-and-a-half-year WIBOR = 0.31%,
- 2 January 2017–13 June 2020 – the whole analyzed period, the risk – free interest rate is a four-and-a-half-year WIBOR = 1.87%.

Effectiveness (or performance) is understood as the relationship between excess return and risk understood in different ways. Both traditional and alternative risk measures are used. The following companies which make up the WIG-Leki index on 15 June 2021 (end of the study period) are analyzed:

- Bioton S.A.,
- Biomed Lublin S.A.,
- Celon Pharma S.A.,
- PZ Cormay S.A.,
- KRKA Polska Sp. z o.o.,
- Mabion S.A.,
- Master Pharm S.A.,
- Pharmena S.A.,
- Sopharma A.D.

Besides, the performance of the WIG-Leki index is analyzed. It reflects the general effectiveness of all pharmaceutical companies which make it up. At the beginning, the statistical analysis was performed. Such distribution features were calculated as mean, standard deviation, skewness, and kurtosis. Weekly data for companies and indexes were downloaded from [www.stooq.com](http://www.stooq.com). In the case of missing data when there were no quotations available for a company

for one week because of no transactions (Sopharma AD and KRKA Polska Sp. z o.o.), quotations from the previous period were taken.

The methods of investment performance valuation can be divided into two groups:

1. Standard efficiency measures. In this group, the Sharpe ratio is used (Sharpe, 1975).
2. Alternative efficiency measures. Here, maximum drawdown measures such as Calmar ratio, Sterling ratio, Burke ratio are applied (Young, 1991; Burke, 1994).

The Sharpe ratio was designed by William Sharpe to compare the performance of mutual funds. The author compared returns and risks of 34 investment funds between 1954 and 1963 and ranked them from the best to the worst (Sharpe, 1966). The Sharpe ratio is often depicted in the following way (Francis, 2000, p. 709):

$$\text{Sharpe ratio} = \frac{r_i^{av} - r_f}{\sigma(r_i)} \quad (1)$$

where:

$r_i^{av}$  – the average value of return on the portfolio of  $i$  assets  
 $\sigma(r_i)$  – the standard deviation of return on the portfolio of  $i$  assets  
 $r_f$  – risk-free interest rate

In the following years, the Sharpe ratio started to be used for other assets or portfolios. It is a relative performance measure of the investment and can be applied to make a comparison between several assets. It cannot be used to measure the performance of a single asset. The same rule applies to other ratios used in this study.

Moving on to alternative measures, the Calmar ratio is depicted as (Young 1991, p. 40; Eling & Schuhmacher 2007, p. 6):

$$\text{CR} = \frac{r_i^{av} - r_f}{-MD_i} \quad (2)$$

where:

$r_f$  – risk-free interest rate  
 $r_i^{av}$  – the average value of the rate of return on  $i$  assets  
 $MD_i$  – the lowest rate of return on  $i$  assets in the assumed period.

As seen from the formula, the Calmar ratio takes into account the lowest return on asset in the analyzed period. It presents the worst-case scenario from the past, which is its advantage. On the other hand, it has the disadvantage of high sensitivity to random returns resulting from low-probability events. The required efficiency is when it is maximized. In order to diminish the sensitivity of the Calmar ratio, the Sterling ratio is applied. It considers the average level of  $N$  maximum negative returns. It is defined (Kestner, 1996, pp. 44–46; Eling & Schuhmacher, 2007, p. 6):

$$SR = \frac{r_i^{av} - r_f}{\frac{1}{N} \sum_{j=1}^N (-MD_{ij})} \quad (3)$$

As with the previously discussed measures, the Sterling ratio is also designed so that higher values are required.

Another alternative ratio used in the study is the Burke ratio. In this case, the excess return is related to the square root of the sum of  $N$  powered lowest returns achieved in the examined period. Mathematically, it can be presented in the following way (Burke, 1994, p. 56; Eling & Schuhmacher 2007, p. 6):

$$BR = \frac{r_i^{av} - r_f}{\sqrt{\sum_{j=1}^N MD_{ij}^2}} \quad (4)$$

The design of the Burke ratio shows that similarly to the performance measures presented earlier, maximum values are required.

### 3 Research Results

The different performance measures applied for the purposes of the analysis are depicted in Tables 10.3 to 10.6. As shown, they do not always lead to the same conclusions. Thus, only these situations are considered here in which all of them show identical results. This additionally means that conclusions on the investment effectiveness of pharmaceutical companies are based on the consideration of different attitudes to risk. Thanks to such methodology, results are more reliable. Descriptive statistics for the companies and indexes examined are depicted in Table 10.1.

In Table 10.1, apart from such measures as variance, standard deviation or mean, which were later used in the calculations of performance measures,

TABLE 10.1 Main statistics for analyzed indexes and companies

Company or index	Mean	Standard deviation	Variance	Min	Max	Skewness	Kurtosis
<i>2 January 2017–23 February 2020</i>							
WIG20TR	0.07	2.11	4.46	-5.64	5.37	-0.15	3.18
WIG-Leki	-0.07	3.81	14.50	-19.49	9.21	-0.90	6.34
Bioton S.A.	-0.58	6.45	41.66	-18.48	26.81	1.11	6.05
Biomed	-0.03	5.15	26.47	-13.75	19.52	0.57	4.52
Lublin S.A.							
Celon	0.33	4.88	23.86	-11.66	21.48	0.55	4.58
Pharma S.A.							
P.Z.Cormay S.A.	-0.43	6.83	46.64	-18.07	23.87	0.50	4.50
KRKA Polska	0.32	2.85	8.10	-9.04	12.29	0.08	5.77
Sp.z o.o.							
Mabion S.A.	-0.22	7.08	50.13	-45.73	19.69	-1.67	13.65
Master	-0.17	5.30	28.07	-17.63	18.67	0.24	5.45
Pharm S.A.							
Pharmena S.A.	-0.67	7.23	52.25	-19.42	30.13	0.40	5.13
Sopharma A.D.	0.13	3.84	14.73	-22.32	20.29	0.09	17.58
<i>24 February 2020 to 15 March 2020</i>							
WIG20TR	-14.15	12.87	165.62	-25.62	-0.23	0.34	1.50
WIG-Leki	-18.47	21.24	451.20	-41.86	-0.39	-0.43	1.50
Bioton S.A.	-14.98	28.46	810.21	-36.96	17.17	0.57	1.50
Biomed	-20.72294	44.09	1943.54	-66.69	21.20	-0.17	1.50
Lublin S.A.							
Celon	-14.50	15.64	244.67	-29.65	1.59	0.11	1.50
Pharma S.A.							
P.Z.Cormay S.A.	-9.81	57.39	3293.93	-51.35	55.68	0.63	1.50
KRKA Polska	-7.34	1.98	3.92	-9.60	-5.92	-0.64	1.50
Sp.z o.o.							
Mabion S.A.	-31.96	37.83	1430.99	-72.48	2.43	-0.29	1.50
Master	-11.42	11.64	135.55	-19.86	1.86	0.63	1.50
Pharm S.A.							
Pharmena S.A.	-10.43	13.11	171.97	-24.25	1.84	-0.21	1.50
Sopharma A.D.	-2.07	3.59	12.86	-6.21	0.00	-0.71	1.50

TABLE 10.1 Main statistics for analyzed indexes and companies (*cont.*)

Company or index	Mean	Standard deviation	Variance	Min	Max	Skewness	Kurtosis
<i>16 March 2020 to 13 June 2021</i>							
WIG20TR	0.76	3.27	10.70	-8.19	11.31	0.43	4.21
WIG-Leki	1.44	7.58	57.50	-14.86	23.96	0.80	3.89
Bioton S.A.	1.41	8.71	75.86	-10.80	49.81	3.07	16.77
Biomed	4.36	23.50	552.06	-28.01	136.07	3.01	16.68
Lublin S.A.							
Celon	0.74	5.58	31.15	-7.80	17.44	0.74	3.11
Pharma S.A.							
P.Z.Cormay S.A.	0.73	12.41	153.89	-22.90	39.67	1.09	4.76
KRKA Polska Sp.z o.o.	0.93	2.93	8.58	-5.70	11.23	0.67	4.44
Mabion S.A.	2.16	16.34	266.90	-42.70	77.93	1.47	9.64
Master Pharm S.A.	0.05	4.69	21.95	-10.13	19.55	0.95	6.58
Pharmena S.A.	1.23	16.26	264.26	-31.40	62.86	1.57	7.20
Sopharma A.D.	0.11	10.10	102.08	-18.35	49.59	1.75	10.26
<i>2 January 2017–13 June 2021</i>							
WIG20TR	0.08	3.21	10.34	-25.62	11.31	-2.56	22.85
WIG-Leki	0.11	5.93	35.16	-41.86	23.96	-1.02	15.27
Bioton S.A.	-0.21	7.82	61.18	-36.96	49.81	1.21	12.74
Biomed	0.94	14.12	199.25	-66.69	136.07	3.93	41.62
Lublin S.A.							
Celon	0.25	5.52	30.52	-29.65	21.48	-0.21	7.00
Pharma S.A.							
P.Z.Cormay S.A.	-0.22	10.29	105.80	-51.35	55.68	0.74	10.57
KRKA Polska Sp.z o.o.	0.39	3.00	8.99	-9.60	12.29	0.07	5.32
Mabion S.A.	0.04	11.69	136.69	-72.48	77.93	0.04	18.91
Master Pharm S.A.	-0.25	5.36	28.72	-19.86	19.55	0.08	5.91
Pharmena S.A.	-0.26	10.67	113.93	-31.40	62.86	1.81	12.45
Sopharma A.D.	0.10	6.24	38.95	-22.32	49.59	2.07	21.18

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOOQ (2021)

skewness and kurtosis were calculated. They show the third and the fourth central moment of the distribution, whereas the mean and the standard deviation are the first and the second. In other words, they provide additional information concerning risk associated with investments in particular entities. The higher the kurtosis, the higher the risk, so the investment efficiency is lower at the same rate of return. As far as skewness is concerned, its positive values are desired to minimize risk.

Correlation coefficients depicted in Table 10.2 show that returns on WIG20TR are highly correlated with returns on the WIG-Leki index and the majority of pharmaceutical companies returns only during the period 24 February 2020 to 15 March 2020. Simultaneously, all correlation coefficients are insignificant. In other periods, they are low. Thus, pharmaceutical companies could be used as diversifying assets for WIG20TR. Given also that many pharmaceutical companies had higher performance measures than WIG20TR, it can be concluded that they are a good option for an investor on the Warsaw Stock Exchange.

TABLE 10.2 Correlation coefficients between WIG20TR return and examined entities. Bolded values are significant at  $p < 0,05$

Company or index	WIG20TR 2 January 2017– 23 February 2020	WIG20TR 24 February 2020 to 15 March 2020	WIG20TR 16 March 2020 to 13 June 2021	WIG20TR 2 January 2017– 13 June 2021
WIG20TR	1	1	1	1
WIG-Leki	0.25	0.93	0.25	0.48
Bioton S.A.	0.11	0.99	0.25	0.37
Biomed	0.10	0.42	0.06	0.20
Lublin S.A.				
Celon	0.20	0.99	0.33	0.43
Pharma S.A.				
P.Z.Cormay S.A.	0.23	-0.01	0.13	0.17
KRKA Polska	0.10	0.86	0.39	0.33
Sp.z o.o.				
Mabion S.A.	0.15	0.95	0.27	0.43
Master	0.13	0.98	0.32	0.34
Pharm S.A.				
Pharmena S.A.	0.09	0.96	0.18	0.21
Sopharma A.D.	-0.03	0.17	0.18	0.10

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOQ (2021)

TABLE 10.3 Performance measures for companies and indexes in 02 January 2017–23 February 2020

Company or index	Calmar	Sterling5	Sterling10	Burke5	Burke10	Sharpe
WIG20TR	64.19	73.58	82.24	32.69	25.71	175.87
WIG-Leki	-5937.76	-160.59	-156.74	-64.10	-46.51	-318.79
Bioton S.A.	-332.29	-471.05	-545.05	-205.65	-167.49	-941.25
Biomed Lublin S.A.	-45.82	-57.44	-67.39	-25.23	-20.74	-121.67
Celon Pharma S.A.	252.62	308.40	330.43	137.08	103.84	586.51
P.Z.Cormay S.A.	-256.11	-294.53	-339.08	-130.62	-105.37	-652.30
KRKA Polska Sp.z o.o.	121.90	149.27	177.77	65.80	54.56	357.59
Mabion S.A.	93.66	208.26	258.69	74.07	68.52	801.97
Master Pharm S.A.	-457.27	-564.23	-679.77	-250.43	-208.95	-1412.91
Pharmena S.A.	-216.37	-237.75	-263.41	-106.08	-82.62	-572.21
Sopharma A.D.	227.66	411.73	566.34	168.99	155.88	1608.24

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOOQ (2021)

Data depicted in Table 10.3 show that during the period 2 January 2017 to 23 February 2020, there were four pharmaceutical companies which achieved better results than the WIG20TR index. These were: Celon Pharma S.A., Sopharma A.D., KRKA Polska Sp.z o.o., Mabion S.A. All the measures applied show the same results.

In the period 24 February to 15 March 2020, the market saw sharp declines, so all performance measures are negative. However, some pharmaceutical companies go down less than the WIG20TR index. As data gathered in Table 10.4 show, different measures give slightly different results; however, all of them support the conclusion that at least three pharmaceutical companies performed better than the WIG20TR index. These were companies such as PZ Cormay S.A., Pharmena S.A., Sopharma S.A.

Between 16 March 2020 and 13 June 2021, there was one company, KRKA Polska Sp.z o.o., which achieved better results than WIG20TR measured with



TABLE 10.4 Performance measures for companies and indexes from 24 February 2020 to 15 March 2020

Company or index	Calmar	Sterling2	Sterling3	Burke2	Burke3	Sharpe
WIG20TR	-5520.51	-6696.38	-9982.37	-4630.99	-4631.17	-10214.33
WIG-Leki	-499899.39	-27255.73	-39657.78	-13997.23	-14004.29	-8737.14
Bioton S.A.	-4051.19	-4820.33	-9983.34	-3127.04	-3348.67	-5972.46
Biomed Lublin S.A.	-3106.60	-4969.31	-9987.95	-2880.33	-3013.62	-5434.71
Celon Pharma S.A.	-4888.75	-6425.30	-9982.80	-4329.63	-4334.33	-9142.28
P.Z.Cormay S.A.	-1910.21	-2304.64	-9974.59	-1183.32	-1595.96	-2177.03
KRKA Polska Sp.z o.o.	-7625.83	-11255.57	-9966.08	-5620.35	-6313.28	-18435.23
Mabion S.A.	-4408.93	-6499.20	-9992.19	-4150.57	-4152.58	-8548.55
Master Pharm S.A.	-5741.88	-6314.89	-9978.16	-4431.97	-4443.23	-37.13
Pharmena S.A.	-4298.75	-6287.98	-9976.10	-4025.33	-4035.18	-34.79
Sopharma A.D.	-3326.35	-6619.87	-9881.05	-3326.27	-3326.31	-98.60

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOOQ (2021)

all the risk-return ratios applied. However, if one considers only alternative measures, not the Sharpe ratio, it can be concluded that four pharmaceutical entities showed a better relationship between the excess rate of return and risk than the WIG20TR index treated as a benchmark. These were WIG-Leki index, Bioton S.A., Biomed Lublin S.A., and KRKA Polska Sp.z o.o. (see table 10.5).

As Table 10.6 suggests, throughout the analyzed period 2 January 2017 to 13 June 2021, WIG-Leki index and three companies performed better than the WIG20TR index: Biomed Lublin S.A., Celon Pharma S.A., and KRKA Polska Sp.z o.o.

To sum up, while different results are produced in different periods of time, there are many pharmaceutical companies which deliver better results than the WIG20TR index in all the periods except in the immediate wake of the COVID-19 pandemic when all world markets slumped. All in all, in order to successfully use pharmaceutical companies as part of an investment portfolio, it is necessary to make the right choice of companies as well as the right prediction of the market situation. In general, pharmaceutical companies are advised to be used as portfolio diversification instruments because of their low

TABLE 10.5 Performance measures for companies and indexes in the period 16 March 2020 to 13 June 2021

Company or index	Calmar	Sterling5	Sterling10	Burke5	Burke10	Sharpe
WIG20TR	923.87	1544.26	1960.64	654.54	573.76	2314.28
WIG-Leki	965.69	1326.33	1762.70	576.83	517.10	1892.53
Bioton S.A.	1298.70	1559.15	2003.96	687.40	602.05	1611.70
Biomed Lublin S.A.	1553.08	1987.71	2373.17	872.49	726.61	1851.92
Celon Pharma S.A.	944.75	1031.98	1162.45	460.62	363.78	1320.71
P.Z.Cormay S.A.	317.98	381.04	492.25	165.74	146.05	587.22
KRKA Polska Sp.z o.o.	1627.26	2362.45	2976.14	1024.23	889.01	3169.16
Mabion S.A.	504.17	895.34	1179.06	344.73	323.92	1317.99
Master Pharm S.A.	44.58	54.23	68.51	23.82	20.66	96.43
Pharmena S.A.	391.09	481.72	657.38	213.43	192.97	755.44
Sopharma A.D.	55.67	66.46	78.90	29.41	24.34	101.13

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOQQ (2021)

or average correlation with the WIG20TR index during typical market conditions and possible higher investment efficiency than the benchmark.

#### 4 Conclusions, Applicability, and Limitations of the Study

The results of the study may be helpful both for investors and market makers seeking to optimize their investment decisions. It is different from existing ones because the literature devoted to pharmaceutical companies often provides research based on fundamental values of pharmaceutical companies when performance is analyzed. Authors do not consider their performance on stock exchanges based on the relationship between the excess rate of return and risk. In contrast, an approach such as that adopted in this study addresses vital aspects because stock market performance is not only based on financial

TABLE 10.6 Performance measures for companies and indexes in 2 January 2017–  
13 June 2021

Company or index	Calmar	Sterling <sub>5</sub>	Sterling <sub>10</sub>	Burke <sub>5</sub>	Burke <sub>10</sub>	Sharpe
WIG20TR	17.77	37.01	54.44	13.97	13.37	141.79
WIG-Leki	<b>18.43</b>	<b>37.87</b>	52.30	<b>14.89</b>	<b>13.84</b>	130.20
Bioton S.A.	-65.70	-115.01	-152.94	-47.13	-42.78	-310.75
Biomed Lublin S.A.	<b>135.08</b>	<b>284.14</b>	<b>376.62</b>	<b>110.68</b>	<b>101.13</b>	<b>638.57</b>
Celon Pharma S.A.	<b>73.48</b>	<b>145.11</b>	<b>184.01</b>	<b>57.78</b>	<b>51.39</b>	<b>394.88</b>
P.Z.Cormay S.A.	-50.38	-84.31	-110.28	-35.43	-31.70	-251.67
KRKA Polska Sp.z o.o.	<b>369.35</b>	<b>455.42</b>	<b>524.00</b>	<b>192.45</b>	<b>155.95</b>	<b>1186.87</b>
Mabion S.A.	0.51	0.93	1.17	0.36	0.33	3.18
Master Pharm S.A.	-144.59	-175.52	-206.11	-77.78	-63.69	-67.36
Pharmena S.A.	-95.31	-114.02	-133.52	-50.73	-41.44	-33.96
Sopharma A.D.	<b>26.76</b>	<b>34.22</b>	<b>41.35</b>	<b>15.11</b>	<b>12.68</b>	<b>-57.52</b>

SOURCE: AUTHOR'S CALCULATIONS ON THE BASIS OF DATA DOWNLOADED FROM STOOQ (2021)

analysis but also on investor sentiment and behavior of market speculators who often make market prices go away from their fundamental values.

The imitation of the study is that it is an index that had to be used as a benchmark. Thus, if an investor plans to build a diversified portfolio consisting of both WIG20TR index stocks and pharmaceutical companies' stocks, it would be necessary either to buy a basket of stocks replicating the index or to use futures contracts. In the latter case, the basis risk arises. It is understood as differences between index and futures contracts quotations which may make the final result slightly different than for the index itself. Apart from that, index design changes over time, so portfolio changes must be made from time to time, which may affect investment performance.

However, there are no doubts that some pharmaceutical companies quoted on the Warsaw Stock Exchange should be considered in portfolio diversification because of their both low and medium correlation with the benchmark used as well as better performance for some of them in all time periods, except for the one at the beginning of the COVID-19 pandemic which triggered a panic in financial markets globally.

Further studies could include portfolio optimization in order to assess what shares of stocks from the pharmaceutical index in the whole portfolio would be desired to minimize risk or maximize the rate of return.

## References

- Mansouri, A., & Bagheri, A. (2015). Evaluating the financial performance and ranking the pharmaceutical companies listed on the Tehran Stock Exchange by using hybrid approaches of fuzzy analytic hierarchy process and VIKOR. *Journal of Health Accounting*, 5(3), 86–107.
- Ali, A. (2020). Working capital, profit and profitability: An absolute and relational study of selected leading Indian pharmaceutical firms. *Accounting*, 6(6), 951–960.
- Anghel, I., Siminică, M., Cristea, M., Sichigea, M., & Noja, M. G. G. (2018). Intellectual capital and financial performance of biotech companies in the pharmaceutical industry. *Amfiteatru Economic Journal*, 20(49), 631–646. <http://dx.doi.org/10.24818/EA/2018/49/631>.
- Baltes, N., & Minculete, G. D. (2014). The analysis of the financial risks in the pharmaceutical industry in Romania. *Revista Economică*, 66(2), 7–15.
- Barbuta-Misu, N. (2013). The effect of leverage on profitability of pharmaceutical companies. *Annals of Dunarea de Jos University of Galati Fascicle I. Economics and Applied Informatics*, 19, 45–52.
- Basha, M. H. (2014). Impact of increasing the crude oil prices on the financial performance of pharmaceutical companies operating in Jordan for the period (2002–2011). A case study of Jordanian Al-Hikma Pharmaceutical Company. *European Journal of Business and Management*, 6(33), 150–157.
- Bernardo, A., & Ledoit, O. (2000). Gain, loss and asset pricing. *Journal of Political Economy*, 108(1), 144–172.
- Burke, G. (1994). A sharper Sharpe ratio. *Futures*, 23(3).
- CMR International. (2006/2007). Pharmaceutical R&D Factbook; PAREXEL's Pharmaceutical R&D Sourcebook 2007–2008. Retrieved June 15, 2021, from <https://stooq.com>.
- Datamonitor. (2008). *Trends in Clinical Trials, Strategies to Enhance Clinical Trial Design*. DMHC2445.
- Eling, M., & Schuhmacher, F. (2007). Does the choice of performance measure influence the evaluation of hedge funds?. *Journal of Banking and Finance*, 31(8), 2635–2637. The version which was used has different page numbers than the one published in the Journal and comes from: [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=943777](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=943777).

- Endri, E., Susanti, D., Hutabarat, L., Simanjuntak, T. P., & Handayani, S. (2020). Financial performance evaluation: Empirical evidence of pharmaceutical companies in Indonesia. *Systematic Reviews in Pharmacy*, 11(6), 803–816.
- Farhan, N. H. S., Alhomidi, E., Almaqtari, F. A., & Tabash, M. I. (2019). Does corporate governance moderate the relationship between liquidity ratios and financial performance? Evidence from Indian pharmaceutical companies. *Academic Journal of Interdisciplinary Studies*, 8(3), 144–157.
- Farhan, N. H. S., Tabash, M. I., Almaqtari, F. A., & Yahya, A. T. (2020). Board composition and firms' profitability: Empirical evidence from pharmaceutical industry in India. *Journal of International Studies*, 13(3), 180–194.
- Fenyves, V., Nyul, B., Dajnoki, K., Bács, Z., & Tömöri, G. (2019). *Montenegrin Journal of Economics*, 15(4), 99–111.
- Francis, J. C. (2000). *Inwestycje. Analiza i zarządzanie*. WIG Press.
- Golec, J., & Vernon, J. A. (2009). Financial risk of the biotech industry versus the pharmaceutical industry. *Applied Health Economics and Health Policy*, 7, 155–165.
- Kannt, A., & Wieland, T. (2016). Managing risks in drug discovery: reproducibility of published findings. *Naunyn Schmiedebergs Arch Pharmacol*, 389, 353–360.
- Kestner, L. N. (1996). Getting a handle on true performance. *Futures*, 25(1), 44–46.
- Korzeniowska, H. (2020). Outsourcing w branży farmaceutycznej. *Świat Przemysłu Farmaceutycznego*, 1/2020. Retrieved June 14, 2021, from <https://przemyslfarmaceutyczny.pl/artykul/outsourcing-w-branzy-farmaceutycznej>.
- Ledley, F. D., McCoy, S. S., Vaughan, G., & Cleary, E. G. (2020). Profitability of large pharmaceutical companies compared with other large public companies. *Journal of the American Medical Association*, 323(9), 834–843.
- Lim H., & Rokhim, R. (2021). Factors affecting profitability of pharmaceutical company: an Indonesian evidence. *Journal of Economic Studies*, 48(5), pp. 981–995. <https://doi.org/10.1108/JES-01-2020-0021>.
- Lowman, M., Trott, P., Hoecht, A., & Sellam, Z. (2012). Innovation risks of outsourcing in pharmaceutical new product development. *Technovation*, 32(2), 99–109.
- Mouri, D., Suman, D., & Kanti, B. S. (2013). Comparison of profitability of listed pharmaceutical companies of Bangladesh. *Journal of Commerce and Accounting Research*, 2(2), 33–38.
- Nickisch, K. J., Greuel, J. M., & Bode-Greuel, K. M. (2009). How can pharmaceutical and biotechnology companies maintain a high profitability?. *Journal of Commercial Biotechnology*, 15, 309–323.
- Nsiah, F., & Aidoo, P. (2015). Financial performance of listed pharmaceutical companies on Ghana Stock Exchange. *Research Journal of Finance and Accounting*, 6, 59–68.
- Rehan, M., Karaca, S. S., & Alvi, J. (2020). Capital structure and financial performance: Case study from Pakistan pharmaceutical sector. *Financial Studies, Romanian Academy*, 24(3), 66–82.

- Sharpe, W. (1966). Mutual fund performance. *The Journal of Business*, 39(1), 119–138.
- Sharpe, W. F. (1975). The Sharpe ratio. *Journal of Portfolio Management*, 21(1), 49–58.
- Stooq. (2021). *Stooq* [Database]. Retrieved June 15, 2021, from [www.stooq.com](http://www.stooq.com).
- Vernon, J. A., Golec, J. H., & Dimasi, J. A. (2010). Drug development costs when financial risk is measured using the Fama–French three-factor model. *Health Economics Letters*, 19(8), 10021005.
- Young, T. W. (1991). Calmar ratio: A smoother tool. *Futures*, 20(1), 40.

# Conclusions

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The third decade of the 21st century has brought new challenges to healthcare systems as well as to the design and implementation of public health policies at both global and country levels. Indeed, the challenges of the COVID-19 pandemic, and its adverse consequences also accentuated the burden of issues recognized prior to the COVID-19 outbreak such as changing demographics including an aging population in developed countries, rising rates of cancer incidence and cardiovascular disease, poor consumer health behavior, negative health impacts of digital technologies and harmful effects of environmental pollution on health. Such issues bring unknown risks to public health. Under rapidly changing external environments, existing paradigms and research methods may no longer be relevant for the mapping of arising problems and the search for solutions. New challenges require creative interdisciplinary approaches. Because health is a key component of human capital, it can be a driver of both development and societal cohesion. This book takes an interdisciplinary approach and applies a variety of conceptual frameworks and mathematical models to explore a wide range of health-related issues. A total of ten chapters report detailed research findings that are based on a variety of unique publicly available data sets subjected to various methods including conceptual modeling, statistical and econometric modeling, hierarchical cluster analysis and an indicator based approach. As such, the book provides examples of how different health-related problems can be studied by combining the efforts of economists, epidemiologists and mathematicians. Three main themes emerge in this book including: (1) risk factors of disease in the European Union (EU) and the United States (US), (2) aspects of the functioning of health care systems in developed countries, including their institutional frameworks and financing, and (3) selected performance measures of the pharmaceutical sector as seen from both a global and country perspective. The analyses presented in the book contribute to the existing health literature by integrating patient treatment with the economic determinants of health care outcomes, including population density, access to financing and institutional frameworks. The book also provides new evidence regarding the pharmaceutical industry including innovation, international trade and company performance.

The key findings that result from the research are as follows:

- There are racial and ethnic disparities in lung cancer incidence rates, mortality, and stage at diagnosis in the US, and these are higher in the State

of Illinois when compared to national averages. These disparities reflect social, economic, and environmental inequalities and correspond with the patterns of concentration of communities with high poverty levels and high rates of smoking.

- The European Union is not homogenous in terms of the effect of risk factors for lung cancer. Four different patterns of potentially modifiable risk factors for cancer emerge and encompass tobacco use, alcohol consumption, air pollution, socio-economic status, and public expenditures on health care.
- Foodborne diseases affect countries at different levels. Low- and middle-income nations are most impacted by such diseases, but there has been a growing number of incidence in high-income countries, including the US. There is a positive association between the consumption of animal products and foodborne diseases.
- There are various institutional traits and pathways to patient care within the healthcare systems in developed countries. Singapore and Sweden appear to be most effective in increasing system efficiency. However, healthcare systems require change and a value-based approach seems to be the best solution because it is based on clinical and cost-effectiveness.
- Under the 2020 Framework Program, the EU has been increasing investments in the health research, demographic change and wellbeing. Nonetheless, there is a striking discrepancy in funds allocation between Western European and Central and Eastern European countries, with the former absorbing a vast portion of EU investments. This trend may result in a widening gap in health-related research between Western and Eastern Europe, thus limiting the development of connections, knowledge and competencies needed for discovering and implementing innovative solutions in health.
- Limited financial access has proved to be associated with adverse public health outcomes in the United States. “Banking deserts” are characterized by low self-reported health status.
- Advances in healthcare highly depend on innovations, including new developments in the pharmaceutical industry and their success in international markets. The US has the largest export market share of pharmaceuticals, followed by the EU. China however, is dynamically growing in this area as it has successfully leveraged financial resources to strengthen its high-technology industries, including pharmaceuticals. Another success feature of the Chinese economy is the country’s strategy towards clusters development in the pharmaceutical and biotech industries. Nevertheless, although both China and the US hold relative specializations in overall medical exports, they do not reveal comparative advantages in the trade of pharmaceuticals used for tackling the COVID-19 pandemic.



Results from the studies contained in this book yield a variety of implications for public health policy and lend implications for the direction of health care reform in a post-pandemic era.

In terms of the chapters contained in the first section of the book, findings indicate that improvements in disease prevention and management can be better implemented through a deeper understanding and ability to alter social, economic, and cultural determinants of health. There is the urgent need for interventions at the national and local level to address disparities in both lung cancer care and the burden of zoonotic foodborne diseases on populations. Given the heterogeneity in disease risk factors across countries, a 'one-size-fits-all' policy may not be effective. Systemic interventions tailored to the specific needs of individual countries appears to be most effective. Furthermore, a holistic, problem-oriented and targeted approach to public health policy should be considered.

When it comes to policy recommendations for the functioning of health-care systems in developed countries presented in the second section of this book, reforms to the management structures of healthcare systems are necessary. These reforms can move in two directions. First, following the example of developed countries (i.e. Sweden), a system of subsidies for less wealthy and rural regions may help to reduce disparities in access to health care. Second, to monitor and improve the performance of healthcare systems while transforming them into value-based personalized solutions, key performance indicators for the health sector should be designed and used to measure efficiency in financing, organization and management.

The third section of the book examines the pharmaceutical sector and how it relates to public support of innovation. Recent tensions in public health and the growing role of pharmaceuticals due to the COVID-19 pandemic may drive governments to pioneer new policy incentives and increase experimentation with policy intervention in order to jeopardize their medical industries and make them less dependent from international suppliers.

In closing, there is an acute need to better track the impact of different policy interventions. This requires the development of adequate evaluation methodologies that capture both the direct and indirect effects of policy interventions. Furthermore, coherence among different policy levels (local, regional, national) seems to be important when making policy interventions more effective.

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