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Three Essays in Health Economics

Dissertation thesis

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Declaration of Authorship

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Abstract

This dissertation thesis is a collection of three essays in health economics that address three challenges of the Czech healthcare system: the economic burden of obesity and smoking, and the revenue vulnerabilities of statutory health insurance (SHI) scheme. The first two essays employ the cost-of-illness method to quantify the economic burden of obesity and smoking, capturing both direct healthcare costs and indirect productivity losses. The resulting costs are substantial, equivalent to 0.8% of GDP in 2018 for obesity and 0.9% of GDP in 2019 for smoking, even though they represent only a lower bound of the total societal burden. The third essay examines the impact of business cycle on SHI revenues, showing procyclicality of overall SHI revenues and their vulnerability to economic downturns. These results highlight the importance of countercyclical mechanisms to stabilize healthcare financing. The primary contribution of this dissertation lies in its comprehensive approach, combining analyses of healthcare costs and revenue instabilities to offer valuable insights for policymakers. The findings emphasize the need for targeted prevention strategies and resilient financing systems to ensure the sustainability of the Czech healthcare system.

Keywords economic burden, smoking, obesity, business cycle, healthcare system's revenues

Title Three Essays in Health Economics

Abstrakt

Tato disertační práce obsahuje tři analýzy v oblasti ekonomie zdravotnictví, které zkoumají tři klíčové výzvy českého zdravotnického systému: ekonomické náklady obezity a kouření a zranitelnost příjmů ve veřejném zdravotním pojištění. První dvě analýzy využívají cost-of-illness (COI) metodologii ke kvantifikaci ekonomických nákladů způsobenými obezitou a kouřením, zahrnující jak přímé náklady na zdravotní péči, tak nepřímé náklady ztráty produktivity. Výsledné náklady jsou významné a dosahují 0.8% HDP v roce 2018 pro obezitu a 0.9% HDP v roce 2019 pro kouření, přestože se jedná pouze o dolní hranici společenských nákladů. Třetí analýza zkoumá dopady ekonomických cyklů na příjmy ve veřejném zdravotním pojištění, odhaluje procykličnost celkových příjmů zdravotnictví a jejich náchylnost na ekonomické krize. Z výsledků vyplývá důležitost využití proticyklických mechanismů ke stabilizaci financování. Hlavním přínosem této práce je komplexní přístup, který kombinuje analýzy nákladů na zdravotní péči a nestabilit příjmů veřejného zdravotního pojištění, a poskytuje tak praktická doporučení pro tvůrce politik. Výsledky poukazují na potřebu cílených preventivních strategií a odolných finančních systémů v České republice.

Klíčová slova ekonomické zatížení, kouření, obezita, ekonomický cyklus, zdravotnické příjmy

Název práce Tři eseje v ekonomii zdravotnictví

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Acronyms

ADF Augmented Dickey-Fuller

AIC Akaike Information Criterion

ATC Anatomical Therapeutic Chemical

BC Business Cycle

BCA Benefit-Cost Analysis

BIC Bayesian Information Criterion

BMI Body Mass Index

CAS Czech Academy of Sciences

COI Cost-of-illness

COPD Chronic Obstructive Pulmonary Disease

CPI Consumer Price Index

CPS-II Cancer Prevention Study II

CSO Czech Statistical Office

DALY Disability Adjusted Life Year

EU27 European Union (27 member states)

EU28 European Union (28 member states)

EHES European Health Examination Survey

EHIF Estonian Health Insurance Fund

EHIS European Health Interview Survey

FCA Friction Cost Approach

GBD Global Burden of Disease

GDP Gross Domestic Product

GHIF General Health Insurance Fund

G20 Group of Twenty

HALE Healthy Life Expectancy

HCA Human Capital Approach

HLY Healthy Life Year

HRQoL Health-related Quality of Life

HR Hazard Ratio

ICD-9 International Classification of Diseases 9th revision

ICD-10 International Classification of Diseases 10th revision

IHIS Institute for Health Information and Statistics

NBER National Bureau of Economic Research

NHS National Health Service

NCD Non-communicable Diseases

NIPH National Institute of Public Health

OECD Organisation for Economic Co-operation and Development

PAF Population Attributable Fraction

PHI Private Health Insurance

PV Present value

QALY Quality Adjusted Life Year

RR Relative Risk

SAF Smoking-attributable Fraction

SAMMEC Smoking-Attributable Mortality, Morbidity, and Economic Costs

SE Standard Error

SHI Statutory Health Insurance

SHS Secondhand Smoke

SIR Smoking Impact Ratio

VLO Value of Lost Output

VSL Value of Statistical Life

VSLY Value of a Statistical Life Year

WHO World Health Organization

WTP Willingness to Pay

YLL Years of Life Lost

YLD Years Lived with Sisability

Introduction

Introduction and overview

In health economics, understanding the dynamics of healthcare financing is essential for ensuring the sustainability of public healthcare systems. This dissertation explores both the inflows and outflows of the Czech healthcare system through three interconnected studies. These essays contain analyses that have been recently published in respectable health economics journals. The first essay (Chapter 1) is based on an article published in the *European Journal of Health Economics* (Landovská & Karbanová 2023). The second essay (Chapter 2) follows an article published in *Applied Health Economics and Health Policy* (Landovská 2024b). Finally, the third essay (Chapter 3) is a slight modification of an article published in the *Health Economics Review* (Landovská 2024a). The first two essays focus on the expenditures, quantifying the economic burden of obesity and smoking — two public health concerns that impose considerable financial burdens on the system — based on the Cost-of-illness (COI) framework. The third essay shifts focus on the financial inflows into the healthcare system, specifically the revenue fluctuations driven by economic cycles. These topics, while distinct, are deeply interlinked, as they collectively explore how individual and systemic factors impose financial strains on society and healthcare systems. The following paragraphs provide a more detailed introduction to each essay.

The first essay focuses on the economic burden of obesity in the Czech Republic in 2018. Increasing prevalence of obesity (Body Mass Index (BMI) ≥ 30) is a pressing public health issue in the Czech Republic as well as world-wide, affecting up to 2.1 billion people (Dobbs *et al.* 2014). The main aim of the first essay is to calculate both direct and indirect costs of obesity. These costs are computed using the COI approach and should be interpreted as a lower-bound of the total burden, as they exclude disutility and intangible costs. Direct costs

(healthcare utilization costs and costs of pharmacotherapy) are calculated using the top-down approach, while indirect costs (absenteeism, presenteeism and premature mortality) are computed using the human capital approach. The resulting annual costs attributable to obesity in the Czech Republic in 2018 were 1.6 billion EUR, corresponding to 0.8% of GDP. Direct costs were 0.56 billion EUR and accounted for 3.4% of Czech healthcare expenditures. The largest indirect costs were attributable to premature mortality (0.39 billion EUR), absenteeism (0.36 billion EUR) and presenteeism (0.27 billion EUR). These results demonstrate that obesity is a serious problem with considerable costs. Several preventive interventions should be applied in order to decrease the prevalence of obesity and achieve cost savings.

Similarly as obesity, smoking is an important risk factor leading to many diseases, which brings substantial healthcare costs but also indirect costs due to decreased productivity. The second essay aims to quantify the economic burden of smoking in the Czech Republic in 2019. Similarly as in the first essay, the COI methodology is applied to calculate the direct costs (healthcare utilization and pharmacotherapy), and the indirect costs (absenteeism, presenteeism, and premature mortality). Total costs of smoking in the Czech Republic in 2019 amounted to 2119.3 mil EUR (0.94% of GDP). Direct costs were 537.0 mil EUR (2.9% of health expenditures in 2019) and indirect costs were 1582.4 mil EUR, mainly driven by the costs of premature mortality (1062.5 mil EUR). Despite the declining trend in the prevalence of smoking in the Czech Republic, the associated costs, which should be interpreted as lower-bound of the societal costs, are considerable. Investments into strategies to reduce smoking continue to be needed.

The first and second essays highlight the economic impact of obesity and smoking, representing significant outflows in the form of healthcare expenditures and lost productivity. These essays fill the gap in literature, as no such comprehensive studies have been done in the Czech Republic previously. Obesity and smoking represent two major contributors to preventable morbidity and mortality, each being associated with a wide range of comorbidities (e.g. cardiovascular diseases, respiratory diseases and cancers). While the results in these essays capture substantial components of the economic burden, namely medical expenditures and productivity losses, they do not account for averting behavior or intangible costs such as pain and suffering, which are addressed separately in Appendix D. These components are excluded from the main analysis to maintain consistency with standard cost-of-illness methodology, which

typically limits the scope to direct and indirect costs. This approach ensures comparability with existing studies and avoids making normative assumptions required by welfare-based valuation methods. Together, these essays paint a comprehensive picture of the economic toll imposed by these behaviors. This exploration of the outflows sets the stage for the subsequent analysis of the system's inflows.

The third essay examines the vulnerabilities of the Statutory Health Insurance (SHI) system, which is largely dependent on wage-based contributions. The SHI scheme is one of two main schemes of health care system financing in Europe. This scheme mainly relies on wage-based contributions from employers and employees and is thus prone to business cycle fluctuations. This turned out to be a problem especially after the Global Financial Crisis of 2008. In this essay, we estimate the magnitude of the effect of the business cycle on health insurance funds' revenues in the Czech Republic where the health care system financing is based on the SHI scheme. The relationship between the business cycle and healthcare system's revenues has not been quantified to this date. We use static and lagged regression models to estimate the impact of business cycle on health care system's revenues. The business cycle is proxied by a range of macroeconomic indicators, such as nominal GDP and unemployment. Using quarterly data from 2000–2017, we examine the effect of business cycle on total revenues and its two main components: the employer-employee contributions and state contributions. The results show significant pro-cyclicality in health insurance funds' revenues, which is mainly driven by employer-employee contributions. Out of all eight business cycle indicators, nominal GDP has the largest effect. The lagged effect of business cycle on healthcare system's revenues is smaller in magnitude compared to contemporaneous relationship, but the lagged model is slightly favored by model selection criteria for most revenue components as it better reflects the real-world timing of how macroeconomic conditions translate into contribution flows within the social health insurance system. State contributions on behalf of economically inactive people do not display a significant relationship with the business cycle in either the static or lagged model. The effect is consistent across different business cycle indicators, although the magnitudes of the effect vary. Counter-cyclical mechanisms are needed to offset this loss of revenues during economic downturns to ensure sufficient resources in healthcare.

The third essay highlights how economic downturns adversely affect healthcare revenues, further straining systems already burdened by rising healthcare

costs. The research underscores the need for countercyclical mechanisms to stabilize healthcare funding during economic recessions, ensuring the continuity of healthcare services. Together, these topics form a comprehensive analysis of the economic pressures on public health and healthcare financing in the Czech Republic.

While each essay in this dissertation addresses a distinct aspect of the Czech healthcare system, the first two essays share a common methodological foundation in applying the COI approach to quantify the economic burden of obesity and smoking. To ensure clarity and comparability across the analyses, the following section outlines the main methodological approaches used in COI studies, with particular focus on those used in this dissertation. This methodological background provides the necessary context for interpreting the findings and understanding the scope and limitations of each study.

Methodological background: valuing the burden of disease

The accurate quantification of the burden of disease plays a key role in health economics research, providing essential insights into the economic and societal impacts of health conditions. The following paragraphs examine the methodological frameworks employed to evaluate these burdens, with a focus on the COI approach. By outlining the key principles, assumptions, and techniques underlying the estimation of direct and indirect costs, we aim to highlight the strength and relevance of the methods used in the subsequent chapters. A clear understanding of these methodologies is crucial for interpreting the results and drawing meaningful policy implications from the analyses.

Non-communicable Diseasess (NCDs) include cardiovascular diseases, diabetes, cancer, chronic respiratory diseases, and mental illness (Bloom *et al.* 2011). Key risk factors that significantly increase the likelihood of developing an NCD are tobacco use, physical inactivity, harmful alcohol consumption, unhealthy diets, and exposure to air pollution (World Health Organization 2023b). According to the World Health Organization (WHO), NCDs are responsible for 41 million deaths annually, accounting for 74% of all global fatalities. The majority of these deaths are due to cardiovascular diseases (17.9 million), cancers (9.3 million), chronic respiratory diseases (4.1 million), and diabetes (2.0 million) (World Health Organization 2023b). Beyond their impact

on health, NCDs pose a significant threat to economic growth, as 17 million of these deaths occur among individuals of working age (Bloom *et al.* 2011; World Health Organization 2023b). Notably, 77% of all NCD-related deaths occur in low- and middle-income countries (World Health Organization 2023b). With an aging global population, the prevalence of NCDs is projected to increase substantially, further exacerbating their impact on public health systems and economies (Bloom *et al.* 2011).

Approaches for evaluating the burden of a disease are generally categorized into non-monetary and monetary methods. Non-monetary methods include metrics such as QALY and DALY. QALY combines the length and quality of life into a single index, providing a measure of the value of health outcomes (Prieto & Sacristán 2003). DALY, on the other hand, quantifies the loss of the equivalent of one year of full health, calculated as the sum of Years of Life Lost (YLL) due to premature mortality and Years Lived with Sisability (YLD) from disease or injury (World Health Organization 2020b). Other non-monetary approaches include Healthy Life Year (HLY), Healthy Life Expectancy (HALE), and Health-related Quality of Life (HRQoL), each offering unique perspectives on disease burden assessment.

Monetary methods used to quantify the burden of disease include the VSL method, the Value of Lost Output (VLO) method and the Cost-of-Illness (COI) approach (Bloom *et al.* 2011). These approaches estimate the financial impact of diseases, enabling policymakers to prioritize interventions and allocate resources effectively. However, there is no universal agreement on the most suitable method, as the choice depends on the specific nature of the health impacts being assessed.

The Value of Statistical Life (VSL) estimates the value society places on reducing the risk of death. This can be assessed through three primary methods: (i) surveys where individuals are asked how much they would pay to reduce their risk of dying (stated preference method), (ii) observations of consumer behavior, such as the amount spent on safety-enhancing products like airbags (revealed preference method), and (iii) analyses of workplace safety improvements, where reduced wages are accepted in exchange for safer working conditions (another revealed preference method). The estimated VSL varies across studies due to differences in samples, risk measures, and modeling specifications. Despite these variations, the median VSL has remained relatively stable, estimated at approximately $7 million in 2000 dollars (Viscusi & Aldy 2003). Interestingly, Aldy & Viscusi (2008) found that VSL follows an inverted

U-shaped relationship with age, peaking between 35 and 44 years. In practice, the value of statistical life is multiplied by the number of deaths due to a disease, yielding the total value of time lost from premature death.

The value of lost output approach (also referred to as the economic growth approach) estimates the anticipated impact of NCDs on a country's aggregate economic output (GDP) by analyzing how these diseases reduce labor, capital, and other production factors (Bloom *et al.* 2011). Macroeconomic models are used to simulate the economic consequences of NCDs by analyzing their impact on economic growth. The WHO's model incorporates this simulation by linking NCDs to reductions in the two primary factors of production, labor and capital, which are modeled as being adversely affected by these diseases (Bloom *et al.* 2011).

The COI approach, which is used in Chapter 1 and Chapter 2, is the commonly used method which views the costs of a disease as the sum of several categories of direct and indirect costs (Bloom *et al.* 2011). There is a variety of approaches within the COI approach (discussed in the following paragraphs), which makes the results of COI studies not directly comparable. The results of COI studies provide an economic burden of a disease which the society bears, compared to a hypothetical scenario where the disease is completely eradicated.

Based on the way in which the epidemiological data are used, COI studies can employ either the prevalence-based or the incidence-based approach. Incidence-based studies estimate the lifetime costs of an illness from its onset to conclusion (cure or death) for cases beginning within the study period, typically a year. These costs include discounted medical, morbidity, and mortality costs over the lifespan of the cohort. In contrast, prevalence-based studies estimate annual costs for all cases within a given year, regardless of when the illness began. They calculate medical care and morbidity costs for the study year, and mortality and disability costs are discounted for patients who die or become permanently disabled during that year until their expected age of death. Prevalence-based studies are more common due to their simplicity, requiring less data and fewer assumptions compared to incidence-based studies. While lifetime costs can be approximated from annual data under steady-state assumptions about disease progression and treatment, such estimates may lack accuracy due to potential changes in medical technology and other factors (Hodgson 1983; 1988; Segel 2006; Jo 2014).

In the essays in Chapter 1 and Chapter 2, the prevalence-based approach

is employed to asses the economic burden of obesity and smoking. Prevalence-based approach is more suitable when the goal is to draw attention to the overall burden of a disease, especially if it has been underestimated by policymakers. It provides a comprehensive snapshot of the disease's impact, identifying major cost components and helping to design cost-containment policies targeting high-expense areas, such as hospitalization or medication. The incidence-based approach is preferable when the focus is on prevention or long-term management. It allows researchers to estimate the potential lifetime cost savings from preventing new cases of the disease. However, it requires the data on incidence of the disease, which may not be available (for example, in the Czech Republic, data on incidence of smoking or obesity do not exist). Additionally, the incidence approach is useful for analyzing the full management of an illness, enabling the development of clinical and therapeutic guidelines to improve efficiency and effectiveness throughout the disease's progression (Tarricone 2006). Although both approaches use the same groups of costs (e.g. medical costs, morbidity costs, mortality costs), incidence costs tend to be lower due to discounting future costs. The greater the length of an illness, the greater is the difference between the two approaches (Hodgson 1983).

In addition to the temporal dimension, COI studies can be conducted using either a retrospective or prospective approach, depending on whether the relevant events have already occurred at the start of the study. In retrospective approach, all relevant events have already taken place. It is less costly and time-consuming because the data already exist. This method is particularly efficient for studying diseases with long durations, provided sufficient observational datasets are available. In prospective approach, the relevant events have not yet occurred, requiring analysts to follow patients over time and design data collection systems, such as questionnaires for patients, families, or healthcare providers. This approach enables the collection of complete and detailed datasets on illness progression and healthcare utilization. The prospective approach is thus more expensive and time-intensive, especially for diseases with longer time spans (Tarricone 2006). In this dissertation, the retrospective approach is used to estimate the economic burden of obesity and smoking.

COI studies typically include two groups of costs: direct costs and indirect costs. Another important component of the burden of disease that is not included in this study is disutility (also called intangible costs), that is, the personal well-being loss associated with pain, grief, suffering, stigma, and reduced quality of life. These costs are widely recognized in the economic lit-

erature and can significantly contribute to the overall burden of disease. As Rice (1967)—the pioneer of the COI methodology—noted in one of the earliest articles describing COI studies:

> [...] Intangible or psychic costs of disease, such as pain and grief, are omitted. These costs do not directly involve a loss of output and are not readily measurable. Several economists feel that ignoring the intangibles may distort the overall economic and social costs because the implicit assumption is that the economic value of intangible losses is zero.

Although not captured within the standard COI framework, studies using QALY or Willingness to Pay (WTP) methods have estimated that disutility may rival or even exceed direct and indirect costs for some conditions. For example, a Belgian study calculating the economic burden of alcohol consumption, tobacco, illegal drugs and psychoactive medication in 2012 found that while direct and indirect costs add up to 4.6 billion euros, the intangible costs are 20.6 billion euros, equivalent to 515 000 healthy years lost (Lievens *et al.* 2017). Another study from Australia found that intangible costs of smoking were equal to $117.7 billion in 2015/16, while the tangible costs were $19.2 billion (Whetton *et al.* 2019). In line with most COI studies, including foundational work by Rice (1967), this study does not quantify intangible costs. Their exclusion, however, implies that the resulting estimates should be interpreted as conservative lower bounds of the true societal cost. To illustrate the potential magnitude of these intangible costs, an indicative estimate of intangible costs associated with obesity and smoking is presented in Appendix D.

Direct costs include healthcare costs, such as hospital stays, physician visits, prescription drugs, and medical supplies, and non-healthcare costs, such as transportation for treatment and care, informal caregiving, and household expenditures. Nonmedical costs, including expenses for research, training, or infrastructure, are generally excluded to avoid double-counting, as these are often embedded within healthcare charges. Chronic diseases typically incur higher direct costs than acute or communicable diseases due to their long-term nature and the adoption of sustained treatment and prevention strategies (Jo 2014; Segel 2006; Bloom *et al.* 2011). Segel (2006) describes three approaches to measure the direct costs: the top-down approach, the bottom-up approach, and the econometric approach.

The top-down approach, also known as the epidemiological or attributable

risk approach, measures the proportion of a disease B that is due to exposure to the disease or risk factor A (for example, large part of costs of diabetes is attributable to obesity) (Bloom *et al.* 2001; Liu *et al.* 2003). To compute the attributable costs, it uses aggregated data and Population Attributable Fraction (PAF). PAF is an epidemiological measure developed by Morgenstern *et al.* (1980). Using relative risks of a disease, it attributes part of costs of disease B to disease A:

$$PAF = \frac{p_A(RR_{BA} - 1)}{p_A(RR_{BA} - 1) + 1}, \tag{1}$$

where p_A is the prevalence of disease A, and RR_{BA} is the relative risk of disease B for people with disease A, compared to those without disease A (Hodgson & Cohen 1999; Rockhill *et al.* 1998). This equation holds only if there is no confounding. Confounding occurs when the association between an exposure and an outcome is distorted by a third variable, such as age or sex, which is linked to both the exposure and outcome, potentially leading to biased estimates. Unlike other biases, confounding can be adjusted for if data on the confounding variable are available. Similarly, effect measure modification, or statistical interaction, arises when the magnitude of the effect of an exposure on an outcome varies based on the level of a third variable, requiring separate analyses to accurately interpret the relationship (Jo 2014; Segel 2006).

The bottom-up approach estimates costs by calculating the average cost of treatment of the illness and multiplying it by the prevalence of the illness (Bloom *et al.* 2001; Liu *et al.* 2003). This method requires detailed data, often sourced from national-level surveys, to measure medical care utilization and determine unit costs. The total cost is obtained by multiplying the quantity of healthcare services utilized by their respective unit costs. While this approach avoids potential misallocations of costs seen in the top-down method, it can be limited by data availability and the complexity of accurately attributing costs to multiple diagnoses. A notable feature of the bottom-up approach is its calculation of average treatment costs by aggregating the costs of various components of care. For example, the average cost of outpatient visits is determined by multiplying the cost of a single visit by the number of visits, and similar calculations are performed for other types of care. This method provides detailed and disease-specific cost estimates but can be resource-intensive due to the need for granular data on service utilization and costs (Jo 2014; Segel 2006; Rice & Miller 1998).

The econometric approach estimates the cost difference between a cohort

with a disease and one without it, typically matching the groups through regression analyses based on demographic factors and other chronic conditions. Within this method, the mean differences approach compares average costs between the cohorts to determine the incremental cost of the disease, often reporting per-case costs rather than total costs (Birnbaum *et al.* 2005; Rubenstein *et al.* 1997; Swensen *et al.* 2004). Alternatively, the multiple-stage regression approach is used when there are numerous zero-cost cases and a few with very high costs, estimating the incremental cost by comparing regression results with and without a disease indicator. This method often involves a two-stage process: first estimating the likelihood of receiving care and then the excess cost if care is provided (Yelin *et al.* 2002; 2000; Greenberg *et al.* 1999). Unlike the top-down approach, which requires cost data and relative risks to calculate Population Attributable Fractions (PAFs), or the bottom-up approach, which depends on multiple data sources for unit costs and healthcare utilization rates, the econometric approach is more data-efficient and often requires only one dataset, making it advantageous in many scenarios (Jo 2014; Segel 2006).

The top-down approach is implemented to estimate the direct costs of obesity and smoking, based on 2018 obesity prevalence, 2019 smoking prevalence in the Czech Republic, and Relative Risks (RRs) values from existing literature. This choice is primarily driven by data availability. Implementing a bottom-up or econometric approach would require patient-level data, which is not accessible in the Czech Republic. Although health insurance funds do collect data on individual healthcare consumption, these records do not include information on patients' BMI or smoking status. Additionally, health insurance funds are generally unwilling to share their data. Conducting a dedicated survey would be necessary to obtain the information required for the econometric or bottom-up approach.

Indirect costs refer to the productivity losses due to morbidity and mortality and they often surpass direct medical costs (Rice & Miller 1998). These costs inherently assign a monetary value to life, a practice that, while common in COI studies, raises ethical concerns. Controversy stems from the variation in estimates and disagreement over the appropriate valuation methods, as well as from the tendency to assign lower values to the elderly and non-working individuals. Despite these challenges, three primary approaches are used to estimate indirect costs: the human capital approach (HCA), the friction cost approach (FCA), and the WTP method (Segel 2006).

The human capital approach (HCA) estimates productivity losses due to morbidity and mortality by calculating the present value of an individual's future earnings as a proxy for their future productivity (Jo 2014). For mortality or permanent disability, this involves multiplying lost earnings at each age by the probability of living to that age, discounting future earnings, and often assuming a modest real annual growth rate (Rice *et al.* 1989). The HCA does not assume full employment but instead takes into account the proportions in each age group that are employed (Pike & Grosse 2018). Although there is a common misconception that the HCA assigns higher values to individuals with higher incomes (Lamsal & Zwicker 2017), most implementations of the HCA rely on statistical averages rather than personal income levels (Max *et al.* 2004). The method also accounts for household work, valuing it as the opportunity cost of hiring a replacement (Hodgson & Meiners 1982), although it is not common in European studies (Pike & Grosse 2018). While being the predominant method used to estimate productivity costs (Pike & Grosse 2018), the HCA has been criticized for overestimating forgone production by assuming workers cannot be replaced, even in contexts of high unemployment, and for inaccuracies in using future earnings to reflect productivity.

The Friction cost approach (FCA) is an alternative method to the HCA, used only in 5–8% of COI studies (Pike & Grosse 2018). Unlike HCA which estimates the value of potentially lost production until retirement, FCA estimates productivity losses during the time it takes to replace a worker, known as the friction period (Koopmanschap *et al.* 1995). The length of the friction period varies across studies from 6 weeks to 6 months (Pike & Grosse 2018). While this approach generally results in lower cost estimates than the HCA, it has been criticized for several reasons. Critics argue that it oversimplifies the impact of illness by assuming replacement workers maintain productivity and ignores costs like leisure and household production (Weinstein *et al.* 1997). Additionally, operational challenges include defining the friction period, which varies between studies, and addressing the "chain of vacancies" created when a replacement is drawn from the employed population (Van den Hout 2010). Despite its controversies, the FCA is seen as a useful lower bound for short-term cost estimates, though its assumptions about labor market dynamics and shadow pricing remain contentious (Koopmanschap *et al.* 1995). In this dissertation, the HCA is used in the baseline model to estimate the economic burden of obesity and smoking. Both essays account for the value of both paid and unpaid work. The FCA is applied in the sensitivity analysis in Chapter 2, high-

lighting how the results can vary depending on the methodology used.

The Willingness-to-Pay (WTP) approach estimates the monetary value individuals would pay to reduce the probability of illness or mortality. WTP methods include surveys, analyzing wage differentials for risky jobs, and examining demand for safety-enhancing products like seatbelts or smoke detectors (Hodgson & Meiners 1982). While conceptually appealing due to its comprehensive consideration of costs and grounding in welfare economics, the WTP approach faces significant challenges. Survey methods often rely on hypothetical scenarios prone to bias, while revealed preference methods risk misrepresenting values due to individual differences in risk aversion or economic opportunities. Furthermore, WTP's reliance on individuals' ability to pay introduces equity concerns, as those most at risk (e.g., the elderly or low-income groups) may lack the financial resources to express their willingness (Hodgson & Meiners 1982).

The most widely used approach to evaluate indirect costs in COI studies is the HCA. It systematically estimates productivity losses by assigning a monetary value to lost paid and unpaid work, but has faced criticism for potentially overstating societal burden by relying on forgone earnings alone (Hodgson & Meiners 1982; Hodgson 1983). In contrast, the WTP approach is grounded in welfare economics: it derives values from individuals' preferences for risk reduction, capturing non-market impacts such as pain, suffering, leisure disruptions, and broader utility losses. Consequently, WTP-based valuations, typically using VSL or VSLY, are recognized as theoretically superior for benefit-cost analysis applications and often yield higher valuations than HCA (Rice *et al.* 1991; Rice 1967). This interpretation aligns with international guidance from sources such as the Organisation for Economic Co-operation and Development (OECD), which explicitly contrasts COI methods with welfare-based approaches (OECD 2012). Similarly, Alberini (2017) emphasizes that while COI-based metrics effectively quantify labour and healthcare expenditures, they omit important welfare losses that WTP methods are designed to capture. Each method offers distinct advantages and trade-offs. The FCA provides more conservative estimates by focusing on the actual period needed to replace a worker, though it requires detailed labor market data and complex modeling. Ultimately, the choice depends on factors such as data availability, policy objectives, and whether one's goal is descriptive burden estimation or welfare-based valuation.

In this thesis, the HCA is used to estimate indirect costs in the baseline model, as it remains the most widely applied method in COI studies and is suit-

able for descriptive burden-of-illness analysis. Its application is also driven by data constraints in the Czech Republic, where essential inputs for implementing a full WTP analysis, such as detailed preference-based risk valuations for obesity or smoking, are not readily available. Nevertheless, it is acknowledged that HCA-based valuations do not conform to the welfare economic framework, which favors WTP-based estimates such as the VSL. As such, the results presented here should be interpreted as a lower-bound estimate of the total societal burden. For smoking, the FCA is additionally applied in sensitivity analysis to demonstrate how cost estimates vary with alternative methods and to partially address the critique that the HCA does not account for labor substitution.[1]

In line with the standard COI methodology, productivity losses are valued using the gross wage, representing the full economic output lost due to absenteeism, presenteeism or premature mortality. This approach captures the cost of forgone labor productivity, not merely the net income of affected individuals. While some authors argue for using the full labour cost (including employer-paid social contributions), others maintain that gross wage sufficiently reflects the value of production lost. The present study does not adopt shadow pricing of labor, as it is not framed as a full Benefit-Cost Analysis (BCA) but rather as a descriptive cost-of-illness (COI) assessment.

The costs of an illness are influenced by how the illness is defined, including diagnostic criteria and whether secondary diagnoses are considered. The definition, often based on International Classification of Diseases 9th revision (ICD-9)/International Classification of Diseases 10th revision (ICD-10) codes, can significantly impact cost estimates, as seen in studies of heart disease and angina, where cost estimates varied dramatically depending on inclusion criteria (Javitz *et al.* 2004). Secondary diagnoses further complicate cost attribution, as their inclusion depends on understanding causal pathways. Methods for handling secondary diagnoses include focusing solely on primary diagnoses, using weighted approaches, or applying incremental cost estimation (Segel 2006). Each method can yield vastly different results, as shown in a study on Chronic Obstructive Pulmonary Disease (COPD) costs, where estimates ranged from $710 million for primary diagnoses alone, over $1.6 billion with an incremental approach, to $2.2 billion with a weighted approach (Ward *et al.* 2000). Recommendations suggest using primary diagnoses for diseases without significant comorbidities, though such cases are rare (e.g., rhinitis,

[1]The FCA approach is not applied in the chapter on the economic burden of obesity, as the author was unaware of the necessary data availability at the time of writing.

some skin diseases). When comorbidities are present, the weighted approach is suggested for conditions where treatment is clearly attributable, such as psychiatric disorders. However, this method has drawbacks, including subjective weight assignments, the risk of double counting, and exceeding total healthcare spending when aggregating costs across diseases. For illnesses with significant comorbidities, such as smoking and obesity, the incremental approach is recommended, though it requires detailed prevalence data by age and gender (Ward *et al.* 2000). This thesis accounts for a number of comorbidities when estimating the economic burden of obesity and smoking. These comorbidities are defined using ICD-10 codes, as identified in the current literature. The incremental approach is applied, utilizing PAF to attribute a portion of a comorbidity's costs to a risk factor based on RR values and current prevalence data.

Sensitivity analysis is an integral component of COI studies, enhancing the reliability of cost estimates by exploring how changes in key parameters affect outcomes. By varying assumptions about discount rates, cost components, and data sources, sensitivity analysis identifies potential uncertainties and strengthens the robustness of findings. For example, adjusting the discount rate in HCA calculations can significantly alter productivity loss estimates, highlighting the importance of transparent and systematic sensitivity testing (Jo 2014). This dissertation incorporates sensitivity analysis to ensure that its conclusions are robust and reliable.

COI estimates serve several key purposes. They help prioritize diseases in policy agendas, guide targeting of specific problems and policies, clarify whether medical or social costs dominate, and provide a baseline to evaluate the effectiveness of health interventions. Additionally, these estimates enable cross-national comparisons of disease impacts and strategies to address them (Jo 2014). The major drawback in COI studies stems from the wide variety of approaches, making it difficult to compare results across studies. If the results of different COI studies are to be compared, special attention should be given to the methodologies used (Rice 2000).

While the methodological choices made in this thesis are primarily grounded in cost-of-illness practices, they are also informed by a broader conceptual understanding of health and its economic value. The following section elaborates on this theoretical foundation.

Theoretical foundations: health as capital and welfare-based valuation

To provide a basis for the valuation methods used in this thesis, this section presents key theoretical contributions from the economic literature on health. These include Grossman's model of health capital, welfare-based critiques of conventional cost-of-illness approaches, and valuation frameworks that incorporate risk, uncertainty, and intangible welfare losses.

Michael Grossman's model of health capital (Grossman 1972) represents a foundational contribution to the economic theory of health and has shaped how economists conceptualize individual health behavior. In this framework, health is not treated as a static condition, but rather as a form of capital stock—a durable good that produces a flow of healthy time. Individuals are not passive recipients of health outcomes; instead, they actively invest in their health through decisions involving time, resources, and behavior.

In Grossman's model, individuals inherit an initial stock of health at birth, which naturally depreciates over time, particularly with aging. However, this stock can be replenished or increased through purposeful investments such as medical care, exercise, healthy nutrition, and preventive behaviors. The central idea is that individuals demand "good health" not only for its own sake, but for two fundamental reasons. First, health directly contributes to well-being and quality of life—it is a consumption good. Second, health determines the amount of productive time available for work and leisure—it is also an investment good.

The production of health involves both market inputs (e.g., medical care) and non-market inputs (e.g., time spent on health-improving activities). The efficiency with which individuals can convert these inputs into health improvements depends on various factors, including their education or general human capital. More educated individuals tend to be more efficient producers of health, as they are better able to interpret health information, adhere to treatment protocols, and make preventive choices.

Importantly, the demand for healthcare is derived from the more fundamental demand for health itself. Medical services are not valued for their own sake but only because they help improve or maintain health. This insight helps explain why changes in health behaviors or constraints—such as aging, income, or opportunity costs—can influence healthcare utilization in non-linear or even counterintuitive ways. For instance, individuals may choose to delay or forego

medical care despite having health needs if the perceived benefit is outweighed by the time, cost, or effort required. Conversely, preventive care may increase with income or education, even when immediate health needs are minimal. Understanding these behavioral responses is crucial for designing effective health policies and interventions, as it highlights that healthcare utilization patterns are shaped not only by clinical need but also by broader economic and personal considerations.

Grossman's framework also provides an economic rationale for observed patterns in health disparities. For instance, higher-income or more educated individuals invest more efficiently in their health and may enjoy both longer life expectancy and fewer productivity losses due to illness. Moreover, the model can explain why older individuals, despite having lower overall health, often spend more on healthcare: their higher depreciation rates require larger investments just to maintain a given level of health.

This conceptualization of health as a produced and managed stock, subject to depreciation and marginal returns, has deeply informed subsequent research, including empirical studies of health behavior, evaluations of disease costs, and debates over healthcare efficiency. It also provides a theoretical foundation for methods used in cost-of-illness studies, where productivity losses and medical spending are understood as economic consequences of diminished health capital.

In what follows, we build on this theoretical base by incorporating key extensions that address important limitations of the health capital model, particularly in relation to the valuation of time and welfare. Notably, the contributions by Harrington and Portney (1987) and Freeman (1993) expand the analytical scope of the health production framework and provide critical support for the methodological choices adopted in this thesis.

One challenge in measuring the economic burden of disease lies in determining which components of morbidity to value and how to do so in a manner consistent with welfare theory. In their influential study, Harrington & Portney (1987) provide a formal critique of the COI approach and propose a broader framework grounded in individual preferences and WTP.

Traditional COI studies typically capture only the direct costs of illness (e.g., medical expenditures) and indirect costs associated with lost market productivity (e.g., wage losses). However, Harrington & Portney (1987) argue that this approach systematically underestimates the welfare loss from illness because it omits two key elements: (i) the value of lost non-market time, such

as leisure and unpaid household work, and (ii) the disutility associated with pain, discomfort, or inconvenience resulting from illness. According to their model, the full WTP to avoid an illness includes not only medical costs and lost earnings, but also the value of defensive expenditures and the intrinsic utility losses caused by morbidity.

Importantly, they show that the COI approach provides a lower bound on the total welfare loss, equal only under highly restrictive conditions. Empirical comparisons cited in their work indicate that WTP estimates can be multiple times higher than COI estimates, particularly in cases where illness affects non-working populations or causes substantial suffering despite minimal time off work.

To make this decomposition explicit, equation 22 in Harrington & Portney (1987) formalizes the marginal willingness to pay to avoid a small increase in illness or risk as:

$$\frac{dI^*}{dP} = w \cdot \frac{dS}{dP} + m \cdot \frac{dS}{dP} - \frac{U_S}{\lambda} \cdot \frac{dS}{dP} + D_P,$$

where:

- I^* is the compensating income variation: the amount of income required to keep utility constant when risk P changes.
- P represents the level of an environmental or health-related risk (e.g., smoking, pollution).
- S is the duration or severity of illness induced by the risk P; $\frac{dS}{dP}$ captures how illness responds to a change in P.
- w is the wage rate, reflecting the opportunity cost of time lost due to illness.
- m is the marginal cost of medical treatment per unit of illness.
- D_P is the level of averting or defensive expenditures taken by individuals to mitigate the health risk.
- U_S is the marginal disutility of illness: how much utility is lost when illness increases.
- λ is the marginal utility of income, used to convert utility losses into monetary terms.

This expression breaks down the full marginal burden of illness into four components: the value of lost earnings ($w \cdot \frac{dS}{dP}$), medical costs ($m \cdot \frac{dS}{dP}$), averting

behavior (D_P), and the monetized disutility of illness ($-\frac{U_S}{\lambda} \cdot \frac{dS}{dP}$). The disutility term, though negative in utility space, contributes positively to the monetary burden since $U_S < 0$. This formulation demonstrates clearly why cost-of-illness studies that omit the last two components systematically understate the total welfare loss associated with illness.

This critique is particularly relevant for the present thesis, which estimates the economic burden of smoking and obesity. Although this work adopts a COI framework, it partially addresses the limitation raised by Harrington & Portney (1987) by incorporating the value of unpaid work, such as domestic labor, into the computation of indirect costs. In doing so, the thesis mitigates the risk of undervaluing morbidity in populations not engaged in formal employment, such as women, the elderly, or informal caregivers. Thus, while the valuation of intangible costs such as pain and suffering remains outside the scope of the baseline estimates (but is computed separately in the Appendix D), the inclusion of unpaid work improves alignment with welfare-based measures of morbidity burden and supports more comprehensive policy evaluation.

Building on the foundations laid by Grossman and the welfare critique of cost-of-illness methods by Harrington and Portney, Freeman's work provides a comprehensive framework for valuing health risks using individual preferences. In his seminal book, *The Measurement of Environmental and Resource Values: Theory and Methods* (Freeman III *et al.* 2014), Freeman formalizes the use of WTP to estimate the economic value of both morbidity and mortality risk reductions. His approach is firmly rooted in welfare economics and widely used in the evaluation of environmental and public health policies.

Freeman emphasizes that health improvements yield benefits beyond avoided costs or productivity gains. These include the utility associated with avoiding pain, discomfort, activity limitations, and risk itself. He demonstrates how the VSL can be derived from individual WTP for small changes in mortality risk, and how similar logic applies to morbidity valuation using WTP to avoid non-fatal illness episodes. Importantly, these measures capture intangible losses that traditional cost-of-illness studies systematically omit.

This perspective supports the inclusion of monetized health losses in economic evaluation, whether derived from WTP, VSL, or summary measures such as QALYs and DALYs. While not included in the baseline calculations, such welfare-based values are presented in Appendix D to complement the main cost-of-illness results.

Taken together, the theoretical frameworks of Grossman, Harrington and

Portney, and Freeman provide a broader understanding of how illness generates both observable and intangible costs. It is important to clarify that the main calculations presented in Chapter 1 and Chapter 2 capture only direct medical costs and productivity losses. They do not include disutility or averting behavior, which form part of the full illness burden defined in the health production function literature. These components are discussed conceptually and monetized separately in Appendix D, and the scope of the main results is made explicit in each chapter. By incorporating unpaid work and presenting separate calculations for intangible losses, this thesis responds to key limitations of standard COI studies and better aligns with welfare-theoretic perspectives.

In summary, this introduction has outlined the thematic and methodological foundations of the dissertation, situating its three chapters within the broader context of health economics and public finance. By analyzing the costs of preventable diseases and the vulnerabilities of SHI revenues, the thesis contributes to understanding the dual pressures facing the Czech healthcare system. Its findings offer guidance for improving both health outcomes and financial resilience through evidence-based policy.

Chapter 1

Economic Burden of Obesity in the Czech Republic[1]

1.1 Introduction

Obesity is a serious global health problem that imposes a substantial economic burden on society. Worldwide rates of obesity have nearly tripled since 1975, and more than 2.1 billion people (30% of the global population) currently suffer from overweight or obesity. Importantly, obesity is a known risk factor for cardiovascular diseases, type II diabetes, and certain types of cancer, contributing not only to high healthcare expenditures but also to large productivity losses. The global economic impact of obesity has been calculated at approximately $2 trillion (2.8% of global GDP), a level comparable to the impact of armed conflict, smoking, or terrorism (Dobbs *et al.* 2014). In OECD countries, 8.4% of healthcare spending is dedicated to treating overweight-related diseases (OECD 2019b).

The COVID-19 pandemic has further intensified concerns about obesity. Numerous studies have shown that overweight and obese individuals face higher risks of contracting COVID-19 and developing more severe symptoms, leading to increased morbidity and mortality (Popkin *et al.* 2020). Moreover, public health restrictions such as social distancing and limited mobility may have contributed to reduced physical activity, potentially accelerating the rise in obesity prevalence and straining healthcare systems further (Popkin *et al.* 2020).

In the Czech Republic, the prevalence of obesity has been rising steadily

[1]This chapter is based on joint work with Martina Karbanová (Landovská & Karbanová 2023).

since the 1990s, both among adults (Bruthans 2019) and children (NIPH 2018). This chapter calculates the economic costs associated with obesity, defined as BMI $\geq$ 30 kg/m^2, in the Czech Republic, using the COI methodology. This approach defines the burden of a disease as the sum of direct medical costs and indirect costs due to lost productivity. The results reflect the magnitude of costs that could be avoided if the disease was eliminated entirely (Byford *et al.* 2000). While the analysis includes healthcare costs, absenteeism, presenteeism, and premature mortality, it does not account for intangible costs such as pain and suffering or costs of averting behavior. These aspects are discussed separately in Appendix D. This study provides the first comprehensive calculation of the direct and indirect costs of obesity in the Czech Republic using the COI method and underscores its substantial economic burden.

1.2 Obesity

Obesity is defined as an abnormal or excessive accumulation of body fat that presents a risk to health (World Health Organization 2020a). It is commonly measured using the Body Mass Index (BMI), a simple index of weight-for-height calculated by dividing a person's weight in kilograms by the square of their height in meters:

$$BMI = \frac{weight}{height^2},$$

According to the WHO, an adult with a BMI of 30 or higher is classified as obese, while a BMI between 25 and 29.9 indicates overweight (see Table 1.1 for more detail). Obesity is a complex condition influenced by various factors, including genetics, metabolism, behavior, environment, and socio-economic status. It is recognized as a significant public health challenge due to its association with numerous chronic diseases, reduced quality of life, and increased healthcare costs (Purnell 2015).

Table 1.1: Obesity classification in adults

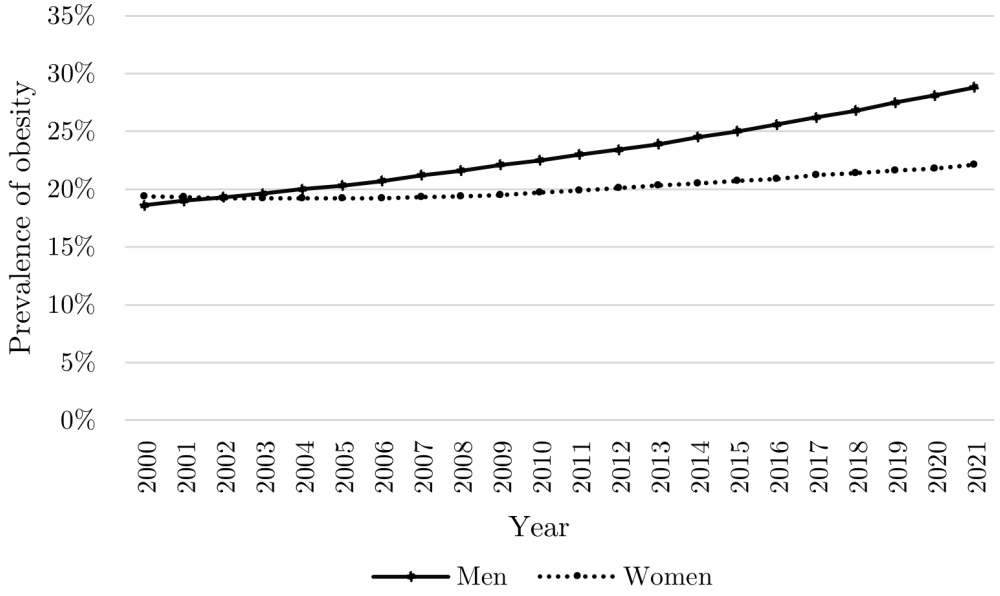
	BMI	Disease risk
Underweight	< 18.5	–
Normal weight	$18.5 - 24.9$	–
Overweight	$25.0 - 29.9$	Increased
Obesity class I	$30 - 34.9$	High
Obesity class II	$35 - 39.9$	Very high
Obesity class III	≥ 40.0	Extremely high

Source: Expert Panel Clinical Guidelines 1998

The data on prevalence of obesity in the Czech Republic are available from various sources, including STEM/MARK, European Health Examination Survey (EHES), European Health Interview Survey (EHIS), MONICA, NCD-RisC study and the Global Health Observatory. These datasets exhibit some variability due to differences in methodology, sampled populations, and age groups considered. While some of these sources are international, they provide country-specific estimates for the Czech Republic. Regarding the evolution of obesity in adults, data from the Global Health Observatory (World Health Organization 2024) indicate a steady increase in obesity rates among adults aged 18+, with men consistently showing a higher prevalence than women since 2002 (see Figure 1.1).

Recent studies emphasize differences in measurement methods. EHIS collects self-reported data, while EHES and MONICA include medical examinations, providing more reliable estimates. Self-reported data are often affected by biases such as underreporting weight. In fact, during the 2019 wave of EHES and EHIS, a comparison showed that 20% of respondents underreported their weight by more than 2 kg/m^2 when translated into BMI units (NIPH 2022a). The age groups also differ in each survey. For example, EHIS looks at health of population aged 15+ years and EHES and MONICA both focus on working-age population only (ages 25–64 years). In 2019, EHES reported obesity rates of 26% for women and 32.9% for men aged 25–64 years. Average BMI was measured as 28.3 kg/m^2 for men and 26.8 kg/m^2 for women (NIPH 2022a). Similarly, MONICA studies from 2015-18 found an average BMI of 29.1 kg/m^2 in men and 27.15 kg/m^2 in women. The prevalence of obesity was found to be

Figure 1.1: Evolution of obesity in adults (18+) in the Czech Republic



Source: Global Health Observatory (World Health Organization 2024)

37.3% in men and 28.2% in women (Cífková *et al.* 2020). According to EHIS, the prevalence of obesity in population 15+ years in 2019 was 21.2% among men and 17.5% among women (IHIS 2022). For the same year, the data from Global Health Observatory showed the prevalence of obesity among adults (18+ years) 27.5% in men and 21.6% in women (World Health Organization 2024).

Although the economic burden of childhood obesity is outside the scope of this study, the trends in the prevalence of obesity in children deserve a note as the prevalence has been rising since the 90s (see Figure 1.2). In children, obesity is not assessed based on BMI, but based on percentile graphs (see Table 1.2). These charts are derived from nationwide surveys that measure children's height and weight within a given year. In the Czech Republic, the reference dataset comes from the 5th Nationwide Anthropological Survey of Children and Youth conducted in 1991. To track changes in obesity prevalence over time, the current distribution of children's height and weight is compared to the reference percentiles, i.e. the distribution of children's height and weight in 1991. Importantly, the 97th percentile is not a fixed threshold but is defined based on the reference population. If more than 3% of children today exceed the historical 97th percentile cutoff, it indicates that the overall weight distribution has shifted upward, meaning children today are generally heavier compared to the reference group. Looking at Figure 1.2, we can see that in

1991, 3% of children were classified as obese, whereas by 2021, this figure had risen to 16.4%. This sharp increase highlights the substantial upward shift in children's weight distribution over the past three decades.

Table 1.2: Obesity classification in children

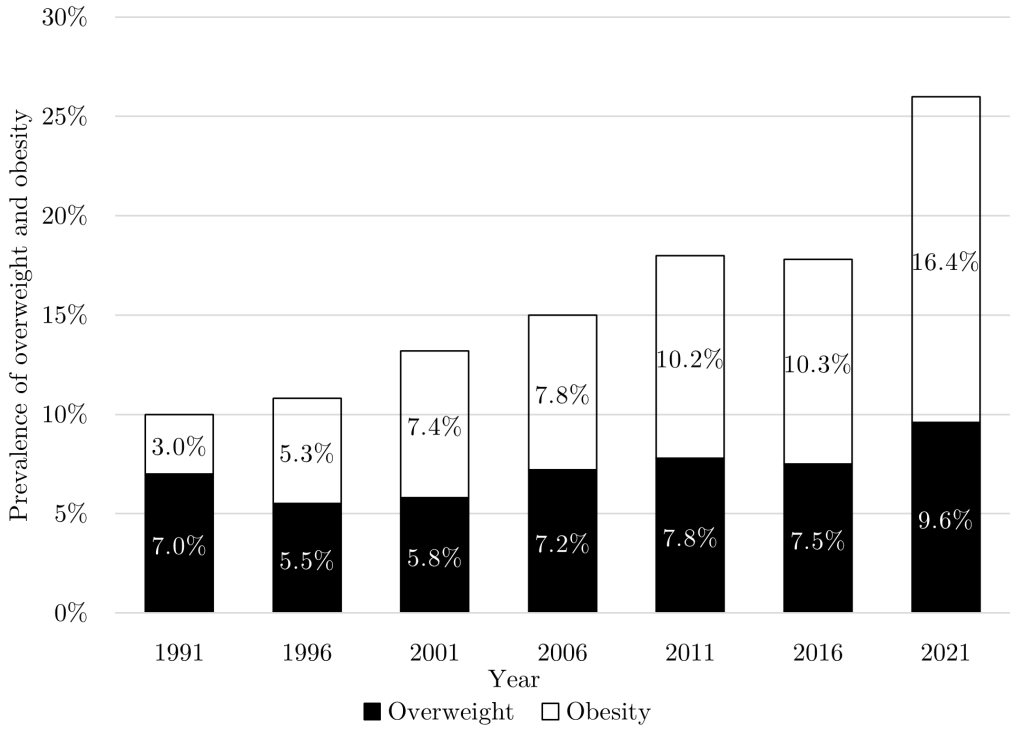
Centile channel	**Classification**
$97 <$	obese
$90 - 97$	overweight
$75 - 90$	plump
$25 - 75$	proportionate
$10 - 25$	thin
< 10	underweight

Source: National Anthropological Research (Vignerová et al. *2006)*

National Institute of Public Health (NIPH) has been monitoring the trends in overweight and obesity in children (5, 9, 13 a 17 years old) since 1996 through the Children Health's Study. Since 1996, the number of obese children has doubled. In 2021, the Association of General Practitioners for Children and Adolescents conducted an anthropometric study of children during preventive check-ups in collaboration with 68 pediatricians. The study aimed to assess the health status of children following the COVID-19 pandemic. The pandemic's restrictions significantly influenced weight gain, particularly among boys and girls around the age of 12. Between the 2019 and 2021 preventive check-ups, a notable increase in BMI was observed among children aged 7, 9, 11, and 13 of both sexes. Alarmingly, the percentage of severely obese boys (BMI above the 99th percentile) aged 9 and 11 rose sharply. Comparing the 2016 Children's Health Study with the 2021 study reveals no change in the proportion of children with low weight (around 10%). However, there was a 7-percentage-point drop in the proportion of children with normal weight. The proportion of overweight children increased by 2 percentage points, while the percentage of obese children (above the 97th percentile) reached 16% in 2021, an increase of one-third (6 percentage points) compared to 2016. The highest obesity rates in 2021 were observed among 11- and 13-year-olds, regardless of gender, with half of the obese children classified as having extreme obesity (above the 99th percentile). The rapid rise in prevalence of obesity among children in the last

5 years has been also driven by 5-year-olds, where the rates rose from 3% in 2016 to 10% in 2021 (NIPH 2023).

Figure 1.2: Evolution of overweight and obesity in children from 1991 to 2021



Source: National Anthropological Research of Children and Adolescents 1991 (Lhotská et al. *1993),* NIPH*: Children Health's Study 1996-2016 (NIPH 2016), Association of General Practitioners for Children and Adolescents (Vážná* et al. *2022)*

Worldwide, the prevalence of obesity has doubled among adults and quadrupled among adolescents since 1990 (World Health Organization 2020a). Over 2.1 billion people worldwide are now classified as overweight or obese, a figure that is 2.5 times greater than the number of undernourished individuals (Dobbs *et al.* 2014). If these trends persist, nearly half of the global population is projected to be overweight or obese by 2030 (Dobbs *et al.* 2014). Obesity is a multifactorial disease influenced by an obesogenic environment, as well as genetic, physiological, environmental, psychological, socioeconomic, and even political factors (World Health Organization 2020a; Wright & Aronne 2012). Additional contributors to the rising prevalence include excessive sugar intake from soft drinks, increasing portion sizes, and a steady decline in physical activity levels (Sahoo *et al.* 2015).

Obesity poses particular risks during childhood, as overweight or obese chil-

dren are more likely to remain obese in adulthood and are at an increased risk of developing non-communicable diseases, such as diabetes and cardiovascular conditions, at an earlier age (Sahoo *et al.* 2015). Fortunately, obesity and overweight are both preventable and manageable. Addressing obesity requires a multisectoral approach, given its multifactorial nature.

An analysis by McKinsey & Company identifies eighteen groups of interventions, including food labeling, media restrictions, education, portion control, and school curriculum changes. Among these, the most impactful interventions in terms of saving DALYs focus on portion control, reformulation, limiting the availability of high-calorie foods and beverages, and implementing weight-management programs (Dobbs *et al.* 2014).

1.3 Literature Review

Significant progress has been made in controlling infectious diseases over the past few decades. However, as the population ages, non-communicable diseases such as diabetes, cancer, and heart disease are becoming increasingly prevalent. This shift is placing substantial demands on healthcare systems and the broader economy, with obesity emerging as a major contributor to these rising costs (Dobbs *et al.* 2014).

Obesity is a complex yet preventable condition that has seen a significant rise in prevalence over the past 30 years, particularly in developed countries. The growing prevalence of overweight and obesity translates into a significant economic burden; for instance, OECD countries allocate approximately 8.4% of their healthcare budgets to the treatment of obesity-related diseases (OECD 2019b).

The estimated costs of obesity in Czechia vary widely, depending on the methodology and data used in each study. Our study is more comprehensive than prior studies, accounting for several categories of direct and indirect obesity-related costs, some of which have not been previously considered in Czech literature. Consequently, we provide a literature review of different cost categories separately. Following standard practive, certain costs, such as intangible costs–those related to pain and suffering, discrimination, difficulty in employment, and biases in education–are not included in the core estimates (Effertz *et al.* 2016). While these costs can be substantial, they are difficult to quantify in monetary terms and are thus typically excluded from cost-of-illness

analyses. To illustrate their potential magnitude, we present approximate estimates of intangible costs associated with obesity in Appendix D.

1.3.1 Direct costs

Numerous studies have shown that obesity is associated with an increased risk of cardiovascular diseases, type II diabetes, and cancers (Guh *et al.* 2009; Dobbins *et al.* 2013). This leads to higher medical costs due to increased use of prescription drugs, outpatient care, and extended hospital stays resulting from post-treatment complications (Effertz *et al.* 2016; Cawley & Meyerhoefer 2012; Konnopka *et al.* 2011; Arterburn *et al.* 2005). There are three primary approaches to estimating the direct costs of obesity: the bottom-up, top-down, and econometric approaches. Of these, the top-down and econometric methods are the most commonly used in the literature. The main distinction is that the top-down approach uses aggregate data and reports results at the national level, whereas the econometric approach relies on individual health expenditure data and typically presents results on a per capita basis.

Current literature indicates that the direct costs of obesity are substantial. For instance, Sturm (2002) estimates that obesity is associated with a 36% increase in inpatient and outpatient spending and a 77% increase in medication costs, while Kleinman *et al.* (2014) finds that direct costs are 50% higher for both obese men and women. Several studies also demonstrate that medical costs increase proportionally with BMI (Wang *et al.* 2006; Raebel *et al.* 2004). Specifically, Wang *et al.* (2006) report that medical and pharmaceutical costs increase by 4% and 7% per unit increase in BMI (for BMI$\geq$25), respectively. Meanwhile, Raebel *et al.* (2004) estimates the per-BMI-unit increase to be 2.3%, primarily driven by prescription drug costs. Borg *et al.* (2005) highlights the differences in hospital stay lengths between obese and normal-weight individuals, with stays increasing with both BMI and age. For instance, a 30-year-old obese man stays 5.7 days longer than his normal-weight counterpart, whereas the difference is 13.4 days for a 60-year-old man.

Table A.1 in Appendix A summarizes studies focusing on the direct costs of obesity. Studies using the econometric approach are predominantly from the USA, where direct per capita costs of obesity among employees are \$1 071–1 549 higher for women and \$392–1 591 higher for men compared to normal-weight individuals, with costs increasing with obesity severity (Finkelstein *et al.* 2005). This study also indicates that while individuals in class III obesity (BMI $\geq$ 40

kg/m^2) represent only 3% of the employed population, they account for 21% of total obesity-related costs. Kleinman *et al.* (2014) reports even higher costs, with more than $2,000 in additional healthcare expenses for obese adult women compared to normal-weight women. In Sweden, Borg *et al.* (2005) estimate the total costs of obesity to be $101 million for women and $169 million for men (ages 30–60), accounting for 2.3% of total healthcare costs.

Studies using the top-down approach differ in the number of comorbidities included, ranging from 4 to 18. The direct costs of overweight and obesity in Germany have been increasing; for example, two studies using the same approach estimated the costs to be €4,854 million in 2002 and €8,647 million in 2008, corresponding to 2.1% and 3.3% of total healthcare costs, respectively (Konnopka *et al.* 2011; Lehnert *et al.* 2015). In Switzerland, medical costs related to obesity represent 2.3–3.5% of total healthcare expenditures (CHF 1,077–1,615 million; Schmid *et al.* (2005)). Estimates for the share of direct obesity costs as a percentage of total healthcare costs include 2.7% in the Republic of Ireland, 2.8% in Northern Ireland (Dee *et al.* 2015), 3.7% in Korea (Kang *et al.* 2011), and 6.7% in Canada (Krueger *et al.* 2015). In the Czech Republic, direct costs of obesity were estimated at 7.6 billion CZK (excluding pharmacotherapy costs) in 2013, accounting for 3.45% of total healthcare expenditures (Tuzarová 2016). An earlier estimate from 2007 placed these costs at 9.5 billion CZK (5.2% of healthcare expenditures), with pharmacotherapy comprising 2.6 billion CZK (Hodycová 2009). Generally, the share of overweight- and obesity-related costs on total healthcare expenses ranges from 2 to 8% (OECD 2019b).

1.3.2 Indirect costs

Absenteeism

Absenteeism, defined as absence from work due to illness, incurs substantial costs as it reduces both the productivity of the absent employee and that of their coworkers, particularly in team-based work environments (Asay *et al.* 2016). The rate of absenteeism due to illness varies internationally, with Czechia recording one of the highest rates in Europe, averaging 16.3 days missed per person in 2018 (World Health Organization 2019). A study in the USA comparing the costs of absenteeism across three risk factors (smoking, physical inactivity, and obesity) and two chronic conditions (hypertension and diabetes) found that obesity contributed the highest costs, totaling $11.2 billion (Asay

et al. 2016).

Table A.2 in Appendix A summarizes current literature on absenteeism costs associated with obesity. Nearly all studies find that absenteeism costs are significantly higher for obese workers compared to normal-weight workers. However, the magnitude of this difference varies across studies, likely due to country-specific factors, variations in data, or differing methodologies. Typically, studies compare absenteeism between obese and normal-weight individuals (e.g., Effertz *et al.* (2016); Dall *et al.* (2009); Finkelstein *et al.* (2005)), though some studies compare individuals with BMI ≥ 25 (thus including those who are overweight) to those of normal weight (e.g., Dee *et al.* (2015); Lehnert *et al.* (2015); Kang *et al.* (2011); Konnopka *et al.* (2011)), which can make results less comparable. Several studies also report absenteeism costs separately for men and women, illustrating gender differences. In all of these studies, absenteeism costs are generally higher for women (Kleinman *et al.* 2014; Lehnert *et al.* 2014; Kang *et al.* 2011; Finkelstein *et al.* 2005). Results are typically provided in monetary terms, though some studies also present absenteeism in terms of days missed. For example, Neovius *et al.* (2012), focusing on absenteeism among Swedish men, reports lifetime productivity losses. Studies examining absenteeism across three obesity classes show that absenteeism rates increase with BMI (Andreyeva *et al.* 2014; Dall *et al.* 2009; Finkelstein *et al.* 2005).

Two studies estimating absenteeism costs in Germany are directly comparable, as they use the same methodology. These studies show that absenteeism costs rose from €646 million in 2002 to €1.28 billion in 2008 (Lehnert *et al.* 2015; Konnopka *et al.* 2011). More recent estimates indicate even higher costs: €2.18 billion (Lehnert *et al.* 2014) and €3.87 billion (Effertz *et al.* 2016). In the USA, annual absenteeism costs range from $104–264 (obesity classes I–III) per person (Dall *et al.* 2009), while Finkelstein *et al.* (2005) estimates costs at $302–805 for women and $70–436 for men. A later study by the same author reports even larger costs: $407–1,262 for women and $277–1,026 for men, amounting to $73.1 billion annually (Finkelstein *et al.* 2010). Andreyeva *et al.* (2014) estimates that absenteeism costs in the USA are $216–348 higher (obesity classes I–III) for obese individuals, totaling up to $8.65 billion annually. In Ireland and Korea, absenteeism costs appear lower, likely due to the lower prevalence of obesity (particularly in Korea) or smaller total populations. In Sweden, lifetime absenteeism costs for obese men are €3,900 higher than for men of normal weight.

Presenteeism

Presenteeism refers to reduced productivity at work due to the presence of mental or physical health complications (Johns 2010). Evidence increasingly shows that the costs of presenteeism associated with chronic conditions often exceed those of absenteeism (Finkelstein *et al.* 2010; Collins *et al.* 2005; Goetzel *et al.* 2004). Several measures of productivity loss have been developed to quantify presenteeism costs, typically through surveys that ask respondents to assess the extent to which their health condition prevented them from working at full capacity. Some surveys are generic and focus on overall health status, while others target specific conditions (e.g., allergies, depression, back pain). Question formats also vary across surveys (Johns 2010). For instance, respondents may rate their agreement with statements like "At work, I was able to focus on achieving my goals despite my (health problem)" (Koopman *et al.* 2002), or answer on a 0–10 scale how much their health problems affected productivity over the past seven days, where 0 indicates "not at all" and 10 means health problems completely prevented them from working (Finkelstein *et al.* 2010). Survey recall periods usually range from one week to one month (Johns 2010).

To our knowledge, obesity-related presenteeism has not yet been measured in the Czech Republic, so we base our estimates on findings from existing literature. We reviewed studies quantifying obesity-related presenteeism in the USA and Europe, summarized in Table A.3 in Appendix A. All studies report a positive association between obesity and presenteeism, though the magnitude of this relationship varies. Some studies compare both obesity and overweight against normal weight (Boles *et al.* 2004; Pelletier *et al.* 2004), while others focus exclusively on obesity versus normal weight (Burton *et al.* 2005; Goetzel *et al.* 2010). A few studies provide results by obesity class (Gupta *et al.* 2015; Finkelstein *et al.* 2010), and only one study examines obesity-related presenteeism by gender (Finkelstein *et al.* 2010). Most studies report results as either the percentage of productivity lost or days lost; one study (Ricci & Chee 2005) reports weekly hours lost, and another (Goetzel *et al.* 2010) provides results in monetary terms. When reported as a percentage of productivity lost, results are converted to days lost, assuming 250 working days per year. For instance, Goetzel *et al.* (2010) estimate that obese individuals lose an average of 1.1 additional days per year due to reduced productivity at work compared to normal-weight individuals. Several studies estimate this difference to be around 3 or 4 days (Boles *et al.* 2004; Burton *et al.* 2005; Ricci & Chee 2005),

though some comparisons are limited by differences in baseline groups, such as the inclusion of underweight individuals or overweight in the comparison group. Studies reporting by obesity class indicate that presenteeism rates increase with BMI, reaching up to 22.7 to 33 days per year for individuals in obesity class III (Finkelstein *et al.* 2010; Gupta *et al.* 2015). This trend is further supported by Kudel *et al.* (2018), who found that presenteeism increases with BMI across 12 occupations. Similarly, Keramat *et al.* (2020) observed a positive longitudinal relationship between presenteeism and obesity across various occupations in Australia. In contrast, Gates *et al.* (2008) found that presenteeism rates were lower for overweight individuals and those in obesity class I compared to normal weight, while rates increased for obesity classes II and III. Based on these studies, we conservatively estimate that the average rate of presenteeism for obese individuals in Czechia ranges from 1 to 4 days, setting a baseline in this study at 2 days lost.

Premature mortality

Excess weight is associated with significant reductions in life expectancy and increases in early mortality (Peeters *et al.* 2003). A substantial body of evidence indicates that obesity and overweight in childhood have unfavorable effects on premature mortality in adulthood (Reilly & Kelly 2011). Obesity and related diseases are estimated to reduce life expectancy by 0.9 to 4.2 years (OECD 2019b). By 2050, approximately 92 million premature deaths due to obesity-related diseases are projected across OECD, Group of Twenty (G20), and European Union (28 member states) (EU28) countries (OECD 2019b), resulting in considerable productivity losses.

Productivity losses due to premature death are typically valued using gross salary up to retirement age. The valuation of lost productivity beyond retirement age varies across studies: some apply the wage of a household worker (Konnopka *et al.* 2011; Effertz *et al.* 2016), others use a percentage of pre-retirement wage (Dee *et al.* 2015), and some do not assign any value to post-retirement years (Tuzarová 2016). Premature mortality is the only component of indirect costs that includes the value of future productivity losses. These losses are discounted to present value using a discount rate, which varies across studies but generally falls between 0% and 10% (Segel 2006).

Current literature on the costs of obesity-related premature mortality is summarized in Table A.4 in Appendix A. Estimates of years of life lost due to

obesity-related premature mortality vary across studies. Peeters *et al.* (2003) estimates that, on average, 40-year-old obese women lose 7.1 years of life, while 40-year-old obese men lose 5.8 years. Fontaine *et al.* (2003) provides estimates for each BMI point starting from a BMI of 25, finding that years of life lost are generally higher for men, ranging from 3 to 13 years for men and from 3 to 8 years for women. In the Czech Republic, the reduction in life expectancy attributable to overweight is estimated at 3.5 years (OECD 2019c).

Productivity losses due to obesity-related premature mortality vary depending on the country, data, and methods used, with results being particularly sensitive to the choice of discount rate. In Germany, two directly comparable studies using the same methodology found that the annual number of deaths due to overweight and obesity-related diseases rose from 36,653 in 2002 to 47,964 in 2008, with associated costs increasing from €3,381 million to €5,669 million (Konnopka *et al.* 2011; Lehnert *et al.* 2015). Effertz *et al.* (2016) estimates substantially higher costs, with 101,886 annual obesity-related deaths translating to 2,072 million years lost and €23.12 billion in productivity losses. In the USA, productivity losses for obesity classes I–III range from $6.9 billion to $25.9 billion ($182–$1,006 per capita, depending on obesity class) (Dall *et al.* 2009). In Sweden, total productivity losses are estimated at $64 million for women and $298.5 million for men (Borg *et al.* 2005). Neovius *et al.* (2012) estimates per capita productivity losses for Swedish men at €52,100–twice the amount for individuals of normal weight. In Northern Ireland and Ireland, obesity- and overweight-related premature mortality costs are estimated at €147 million and €593 million, respectively (Dee *et al.* 2015). In Korea, productivity losses are estimated at €70 million for women and €374 million for men (Kang *et al.* 2011). Lastly, obesity-related premature mortality costs are estimated at 395 million CZK for women and 800 million CZK for men in the Czech Republic (Tuzarová 2016). Fontaine *et al.* (2003) also demonstrates that the costs of premature mortality increase with BMI; for example, a 20-year-old adult with a BMI$\geq$ 45 is expected to lose 13 more years of life compared to a normal-weight individual.

The results from the studies mentioned above indicate that costs are substantially higher for men than for women. This difference may be attributed to several factors: men typically have higher wages, a higher retirement age than women, or a higher prevalence of obesity.

1.3.3 Previous findings from the Czech Republic

Only a limited number of studies have quantified the economic burden of obesity in the Czech Republic. For example, Hodycová (2009) calculated direct obesity-related costs in 2007 at 9.5 billion CZK (342.7 million EUR), with pharmacotherapy accounting for 2.6 billion CZK. Roubík (2011) reported pharmaceutical costs for three major obesity-related comorbidities (type II diabetes, cardiovascular diseases, and cancers) at 8.3 billion CZK, with total healthcare costs for these conditions reaching 38.5 billion CZK (12.8% of the healthcare budget in 2009)[2]. Nejedlá (2014) calculated the direct and indirect costs of obesity at 20.3–42.5 billion CZK (804.3–1684 million EUR) and 17.2–37.8 billion CZK (681.5–1497.8 million EUR), respectively, although these estimates largely rely on foreign studies. Tuzarová (2016) analyzed both direct and indirect costs of obesity in 2013, encompassing 18 comorbidities, absenteeism, and premature mortality, with total costs calculated at 12.1 billion CZK (466.6 mil EUR, 7.6 billion CZK in direct costs and 4.5 billion CZK in indirect costs). This corresponded to 0.3% of GDP in 2013.

1.4 Data

Table 1.3 summarizes the data used in the baseline model. The healthcare utilization costs and costs of pharmacotherapy in 2018 are obtained from the General Health Insurance Fund (GHIF) jointly for men and women (GHIF 2018a; GHIF 2018b), which are extrapolated to the whole population[3]. The data from GHIF on healthcare utilization costs contain the costs of inpatient care (care provided by hospitals, specialized treatment institutions, long-term care facilities, hospices, and also outpatient care delivered within these institutions), outpatient care (services provided by general practitioners and specialists, as well as diagnostic, rehabilitation, and home care, and also transportation of outpatient healthcare workers, including emergency medical services) and the costs of medical transport services and emergency rescue services. The data from GHIF did not include the costs for capitation payments, prescription

[2]These represent the total healthcare costs of the comorbidities, not specifically costs attributable to obesity.

[3]The extrapolation coefficient is equal to 1.79 as 5.95 million people were insured at GHIF in 2018, while the total Czech population was 10.65 million. In the Czech Republic, all permanent residents are required to be insured with one of the seven health insurance funds, ensuring nearly 100% coverage. GHIF is the largest of these funds, covering the majority of the Czech population.

medications, spa treatments, health resorts, and reimbursements for physician home visits, because the documents submitted by healthcare providers to GHIF in these segments do not contain the ICD-10 codes. Therefore, it is not possible to assign these costs to specific diseases.

The data for computation of costs of absenteeism and premature mortality in 2018 are obtained from the Institute for Health Information and Statistics (IHIS), specifically from the Information System Incapacity for work (IHIS 2018) and the Information System Deaths (IHIS 2018). For each comorbidity, they are available for 5-year age groups for men and women separately. The estimation of costs of presenteeism is based on literature review.

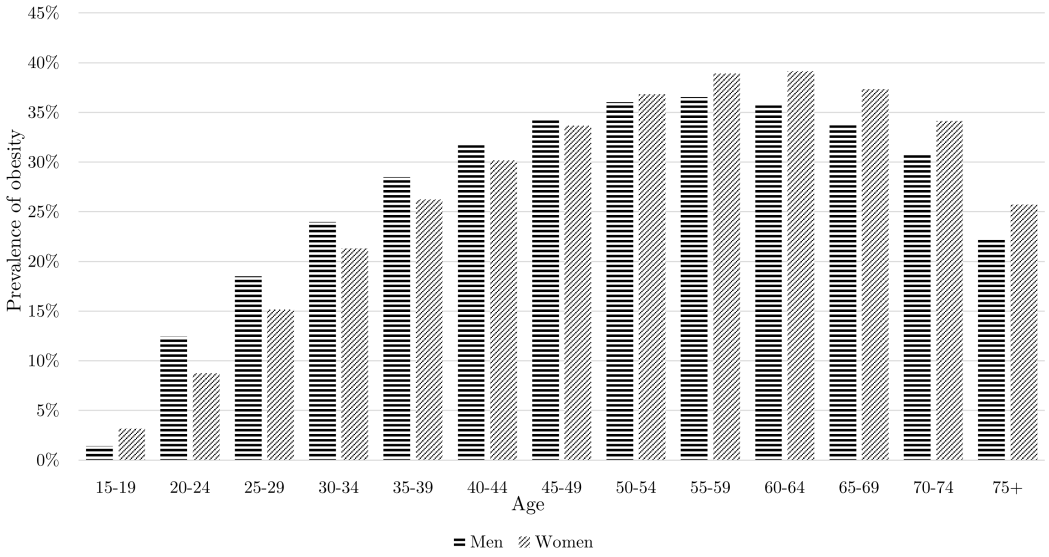
Prevalence of obesity in the Czech Republic is taken from the NCD Risk Factor Collaboration (NCD-RisC) study with the most recent data being from 2016. This study provides the prevalence of obesity in 200 countries based on data measured by physicians. The data are stratified into 5-year age groups (see Figure 1.3), enabling more precise cost calculations. The age-standardised prevalence of obesity in population 20 years and older is 27.3% for men and 26.5% for women (Abarca-Gómez *et al.* 2017).

For this study, obesity is defined as BMI≥30, without distinguishing between obesity classes (I-III). This decision is driven by two main factors. First, the primary aim is to estimate the overall burden of obesity in the Czech Republic rather than the differential impact of obesity severity. Second, the relative risk (RR) estimates used in the calculations correspond to obesity defined as BMI ≥30, and disaggregated RR data for different obesity classes are not available. Given these data constraints, a binary classification (obese/non-obese) provides the most reliable and consistent approach for our analysis.

Relative risks used in this study are based on two high-quality meta-analyses: Guh *et al.* (2009) and Dobbins *et al.* (2013). Guh *et al.* (2009) conducted a systematic review of 89 epidemiological studies published between 1994 and 2006, examining the association between obesity (BMI≥30) and 18 comorbidities. Only prospective cohort studies were included, with a majority conducted in the US (55%) and Europe (40%). The meta-analysis used random-effects models based on maximum likelihood estimation and adjusted for key demographic variables such as age, sex, and ethnicity. However, the study did not adjust for physical inactivity, an important risk factor correlated with obesity and independently associated with some comorbidities, due to inconsistent reporting across studies. This omission may introduce omitted variable bias, potentially leading to an overestimation of the impact of obesity. Dobbins *et al.* (2013)

performed a systematic review and meta-analysis of 57 studies (43 cohort and 14 case-control) published between 1985 and 2011 to assess the association between obesity and 13 types of cancer. Most included studies originated from the US, Sweden, Norway, and Japan. The authors used the DerSimonian and Laird random-effects model to pool estimates and adjusted for various confounders, although behavioral factors were not consistently specified. Despite some limitations, especially regarding adjustment for lifestyle variables such as diet and physical activity, these meta-analyses provide the most comprehensive and systematically derived RRs currently available. The use of such pooled estimates allows for consistent application across diseases and enhances the comparability of results in cost-of-illness analyses. However, potential residual confounding should be acknowledged when interpreting the results.

Figure 1.3: Prevalence of obesity in the Czech Republic (2016)



Source: NCD-RisC study (Abarca-Gómez et al. *2017)*

Paid work is valued by the average gross salary for each gender and age group in 2018 (Czech Statistical Office 2018b). The average daily amount of hours spent doing housework was estimated to be 3 hours for women and 2 hours for men (CAS 2016). The value of unpaid work is approximated by the average wage of cleaning services workers in 2018 (the average hourly wage is 87 CZK/hour (AEIS 2018)). Life expectancy in 2018 is derived from the Czech Statistical Office (CSO) (Czech Statistical Office 2018a) and the number of employed people aged 25-64 years in 2018 is obtained from Eurostat (Eurostat 2018a).

Table 1.3: Data sources

Measure	Data source	Year
Direct costs		
Healthcare utilization	General Health Insurance Fund (GHIF 2018a)	2018
Pharmaceuticals	General Health Insurance Fund (GHIF 2018b)	2018
Indirect costs		
Absenteeism	Information System Incapacity for Work (IHIS 2018)	2018
Presenteeism	Literature review	NA
Premature mortality	Information System Deaths (IHIS 2018)	2018
Other sources		
Prevalence of obesity	NCD-RisC Database (Abarca-Gómez *et al.* 2017)	2016
Relative risks	Guh et al. (Guh *et al.* 2009)	1994–2006
	Dobbins et al. (Dobbins *et al.* 2013)	1985–2011
Gross salary	Czech Statistical Office (CSO 2018)	2018
Unpaid work	Czech Academy of Sciences (CAS 2016)	2015
Value of unpaid work	Average Earnings Information System (AEIS 2018)	2018
Life expectancy	Czech Statistical Office (CSO 2018)	2018
Employed population	Eurostat (Eurostat 2018a)	2018

1.5 Methodology

This study applies the cost-of-illness (COI) framework to quantify the economic burden of obesity. Within this framework, two main approaches are commonly used: (i) the prevalence-based approach, which calculates the costs associated with all existing and new cases within a specific year, including years of life lost due to premature mortality (discounted to present value); and (ii) the incidence-based approach, which assesses the lifetime costs associated with all new cases or deaths occurring in a given year. To capture the annual economic burden of obesity in the Czech Republic, the prevalence-based approach is adopted.

The analysis focuses on tangible costs only, specifically direct medical expenditures and indirect productivity losses. Intangible costs, such as pain, suffering, and other reductions in well-being, as well as averting behaviors, are excluded from the baseline calculations. These components are conceptually important but methodologically challenging to quantify. They are discussed and partially addressed in Appendix D, where complementary estimates based on VSL and QALY/DALY valuation are presented.

All cost components were originally obtained in CZK and subsequently

converted to EUR using the European Central Bank's average exchange rate for 2018 (1 EUR = 25.647 CZK).

1.5.1 Direct costs

Direct costs of illness include all expenditures related to its prevention, treatment and rehabilitation (World Health Organization 2009). The top-down approach, which measures the proportion of a disease that is due to exposure to risk factor, is used. This approach uses aggregated data, along with PAF, which is used to determine the attributable costs. For example, it attributes part of costs of diabetes to obesity (Segel 2006).

Due to data constraints specific to the Czech Republic, the computation of direct costs is divided into two components: healthcare utilization costs and pharmaceutical costs. The reason is that the healthcare utilization costs are documented with ICD-10 codes, whereas pharmaceutical costs are documented with Anatomical Therapeutic Chemical (ATC) classification codes.

As in the rest of the thesis, these calculations include only tangible direct costs. Intangible costs, such as pain, suffering, and loss of quality of life, are not accounted for in this section but are addressed separately in Appendix D.

Healthcare utilization costs

Healthcare utilization costs are computed in the following way:

1. Identify the comorbidities of obesity, i.e. the diseases that are more likely to occur if a person suffers from obesity.
2. Find the RR for each comorbidity c (RR_c). That is, how much more likely is a disease to occur in population with obesity as opposed to population with normal weight. $RR = \frac{r_1}{r_2}$, where r_1 is the probability of disease at obese population and r_2 is the probability of disease at normal weight population.
3. Find prevalence (p) of obesity in the Czech Republic, i.e. the proportion of population whose BMI exceeds 30 kg/m^2.
4. Compute PAF_c (population attributable fraction for comorbidity c), which tells us what fraction of disease's costs is attributable to obesity:

$$PAF_c = \frac{p \cdot (RR_c - 1)}{p \cdot (RR_c - 1) + 1} \tag{1.1}$$

The PAF_c does not take into account ages nor genders as the data on healthcare utilization costs are provided for each diagnosis without the distinction of age groups or gender. For instance, PAF_c for stroke is equal to 11%, meaning that 11% of healthcare costs of stroke are caused by obesity.

5. Compute the healthcare utilization costs attributable to obesity:

$$HC = \sum_c PAF_c \cdot C_c, \tag{1.2}$$

where HC are the healthcare utilization costs attributable to obesity and C_c are the healthcare utilization costs associated with comorbidity c. The healthcare utilization costs are obtained from the General Health Insurance Fund and contain all the costs of patients that had a comorbidity of obesity (e.g. Diabetes II mellitus with ICD-10 codes E11, E13 or E14) as the main diagnosis, i.e. it was the main cause of receiving a treatment.

Costs of pharmacotherapy

Since healthcare utilization costs do not contain the costs of pharmacotherapy[4], we include these separately by identifying the ATC groups which are related to comorbidities of obesity. We include five groups of pharmaceuticals based on Hodycová (2009) and Dee *et al.* (2015):

- for the cure of obesity
- for the cure of diabetes mellitus
- for the cure of cardiovascular diseases
- for the cure of cancer
- for the cure of arthrosis

Specific ATC groups are available in Table 1.7. The costs of pharmaceuticals provided by the General Health Insurance Fund (GHIF) contain only the costs used in the treatment of the comorbidity (e.g. if we take the example of diabetes mellitus, these costs are not the costs of pharmaceuticals incurred by all diabetic patients, but they are the costs of pharmaceuticals used in the treatment of diabetes). Pharmaceutical costs PC are computed as:

$$PC = \sum_c PAF_c \cdot PC_c, \tag{1.3}$$

[4]ICD-10 codes are not available for prescribed medicaments.

where PC_c are the pharmaceutical costs of ATC group which is related to a comorbidity of obesity c. $PAFs$ are used to compute the part of pharmaceutical costs that are directly attributable to obesity.

1.5.2 Indirect costs

Indirect costs of illness are the value of lost production due to morbidity or mortality. This lost time is multiplied by age- and gender-specific average gross wage rates to calculate the indirect costs (World Health Organization 2009). The Human capital approach (HCA) is used to estimate the indirect costs. It takes the patient's perspective and counts any hour not worked as an hour lost. The value of housework is also incorporated into the lost production and it is valued as the opportunity cost of hiring a replacement from the labor market (Effertz *et al.* 2016).

We include three common components of indirect costs: absenteeism, presenteeism and premature mortality. For premature mortality, the present value of future lost earnings is computed using a discount rate. The total lost productivity is the sum of paid work (measured in days per month) and unpaid work (measured in hours per month). Paid work is valued by gender- and age-specific monthly gross salary, whereas unpaid work is valued by the average hourly salary of a household worker[5]:

$$P_{ag} = PW_{ag} \cdot GS_{ag} + UW_g \cdot W_{HW}, \tag{1.4}$$

where P_{ag} refers to age- (a) and gender- (g) specific evaluation of productivity lost, PW_{ag} stands for the age- and gender-specific amount of paid work, GS_{ag} refers to age and gender-specific gross salary, UW_g stands for the gender-specific amount of unpaid work and W_{HW} stands for the wage of household worker[6]. The productivity lost from paid work is considered until the average retirement age (63.2 years for men and 62.7 years for women (OECD 2018)), whereas the productivity lost from unpaid work is considered until the average life expectancy age (76 for men and 82 for women (Czech Statistical Office 2018a)). The data on indirect costs (specifically absenteeism and premature mortality) allow for more detailistic computation of costs attributable to obesity, so PAF_{acg} which is specific for age (a), comorbidity (c) and gender (g) is

[5]We approximate this by average wage of cleaning services worker (AEIS 2018).
[6]The wage of household worker is not available for men and women separately.

used:

$$PAF_{acg} = \frac{p_{ag} \cdot (RR_c - 1)}{p_{ag} \cdot (RR_c - 1) + 1} \tag{1.5}$$

Absenteeism

Absenteeism refers to absence from work due to illness. To calculate the number of days absent from work attributable to obesity, we use the number of terminated cases of incapacity for work for obesity-related comorbidities in days from 2018 provided by the IHIS (IHIS 2018).

The number of days spent absent from work due to obesity for age (a), comorbidity (c) and gender (g) are computed as:

$$DA_{acg}^{obesity} = DA_{acg} \cdot PAF_{acg}, \tag{1.6}$$

where DA_{acg} stands for age- (a), comorbidity- (c) and gender- (g) specific days absent. Total costs due to obesity-related absenteeism (IC^{abs}) are monetarily valued as:

$$IC^{abs} = \sum_a \sum_c \sum_g DA_{acg}^{obesity} \cdot P_{ag}, \tag{1.7}$$

where P_{ag} is the evaluation of paid and unpaid work as specified above.

Presenteeism

To the best of our knowledge, no survey measuring obesity-related presenteeism has been conducted in the Czech Republic so far. Our assumption is based on literature review summarised in Table A.3. The review contains studies predominantly from the USA. Only one study focuses on five European countries (France, Germany, Italy, Spain and UK) and states that obesity-related presenteeism means 4-33 more days lost compared to normal weight, depending on obesity class (Gupta *et al.* 2015). Based on the literature review, we assume that the average annual rate of presenteeism for obese individuals in the Czech Republic is 2 days lost for both men and women. This assumption is rather conservative, but we prefer a conservative approach rather than overestimating the costs. In sensitivity analysis, we also estimate the costs for 1, 3 and 4 days lost due to presenteeism. Yearly lost productivity due to presenteeism is valued as:

$$IC^{pres} = \sum_g p_g \cdot E_g \cdot PL \cdot P_g, \tag{1.8}$$

where E_g is the number of employed people in working-age population (distinguished by gender g), and $p_g \cdot E_g$ is the number of obese people in labour force (p is prevalence of obesity in working-age population, i.e. 25-64 years old), PL stands for productive days lost due to presenteeism and P_g is the gender-specific valuation of paid and unpaid work[7].

Premature mortality

To calculate the costs of premature mortality due to obesity-related diseases, we use the data from the IHIS (IHIS 2018). These data contain the number of deaths at each age category due to comorbidities of obesity. To evaluate the lost productivity, we take into account not only the productive years lost (i.e. years before retirement age), but also the years after retirement age as not including this would imply that life of retired people has no value (World Health Organization 2009). The productive years are valued by average monthly salary specific for 5-year age group and gender, and by the value of unpaid work (approximated by hourly salary of cleaning services employee), assuming that both men and women perform daily unpaid work according to a survey by the Czech Academy of Sciences (CAS). The years after retirement age and before life expectancy are valued by the amount of unpaid work according to a survey by the CAS (CAS 2016, Konnopka *et al.* (2011)).

In COI studies, costs are computed for one given year, but in case of premature mortality, the net present value of future lost earnings is included (Segel 2006). The value of productivity losses is discounted to present value using a discount rate:

$$NPV = \sum_{t=0}^{n} \frac{FV}{(1+i)^t}, \tag{1.9}$$

where i is the discount rate, FV stands for future value and t is the amount of years lost. The discount rate usually ranges between 0 and 10% (Segel 2006). We use the discount rate of 3% as suggested by Segel (2006), but because the discount rate affects the results largely, we also perform sensitivity analysis with discount rates 1% and 5% (Hodgson & Meiners 1982).

[7] We do not distinguish salaries based on age in this part: $P_g = PW_g \cdot GS_g + UW_g \cdot W_{HW}$.

The obesity-attributable costs of premature mortality are computed as:

$$IC^{mort} = \sum_{a}\sum_{c}\sum_{g} PAF_{acg} \cdot M_{acg} \cdot \left(0.5 \cdot P_{ag} + \sum_{t=1}^{ret-1} \frac{P_{ag}}{(1+i)^t} + \sum_{t=ret}^{exp} \frac{UW_g \cdot W_{HW}}{(1+i)^t}\right), \tag{1.10}$$

where M_{acg} stands for age-, comorbidity- and gender- specific number of deaths. Only half of the productivity is accounted for in the first year ($t = 0$) to correct for different occurences of death during the year. Until retirement (ret), the lost productivity is valued by both paid and unpaid work. From retirement age until the average life expectancy age (exp), the lost productivity is valued by the value of unpaid work. We do not take into account background death rates in future years (i.e. deaths that would have occurred separate from obesity-related causes) as it is not standard in this methodological approach.

1.5.3 Sensitivity analysis

The robustness of our results is tested using sensitivity analysis where we vary several essential parameters used in the evaluation of costs of obesity:

- PAFs are recomputed using the 95% confidence interval of relative risks from Dobbins *et al.* (2013) and Guh *et al.* (2009).
- PAFs are recomputed using the relative risks from the Dynamo project. This project provides relative risks for selected diseases as indicated in Table 1.4 and is based on studies from Europe. Additionally, it provides adjustments of relative risks based on age.
- Prevalence data from the EHES (NIPH 2014) and EHIS (IHIS 2014) are used. These surveys were conducted in 2014 in the Czech Republic[8]. EHES is a survey focusing on working population (aged 25–64) and the data are collected by physicians. EHIS focuses on all population aged 15+ years and the data are self-reported. We use mainly the EHES data and complement them with the EHIS data in age groups 15–24 and 65+. The prevalence of obesity in population 15+ years is 25.3% for men and 22.9% for women (IHIS 2014), while the prevalence in working population (25–64 years) is 29.1% for men and 24.7% for women (NIPH 2014).

[8]A new survey started in 2019, but due to the lack of respondents, the data are not available in 5-year age groups.

- Discount rate of 1% and 5% is used for computing the costs of premature mortality.
- Unpaid work is completely excluded from total costs.
- Presenteeism is computed for missing 1, 3 and 4 days of work (baseline value is 2 days).

Table 1.4: Relative risks from the Dynamo project

	Women	**Men**	**Age adjustment**
Ischemic heart disease	2	2	×0.70 age over 65
Stroke	1.55	1.5	×0.75 from age 65
Diabetes	7	5.5	×0.92 from age 60
			×0.90 from age 75
Breast cancer	1	1	×1.25 over age 50 women
Colorectal cancer	1.1	1.4	×0.90 from age 45
Kidney cancer	1.8	1.55	–
Gallbladder cancer	1.85	1.25	×1.17 from age 45 men
			×0.80 from age 45 women
Endometrial cancer	2.5	–	–

Source: The Dynamo Project (Lobstein & Leach 2010)

1.6 Results

1.6.1 Direct costs

Healthcare utilization costs

Table 1.5 lists the relevant comorbidities of obesity along with the ICD-10 codes and PAF computed based on the prevalence of obesity in the Czech Republic[9] and relative risks (Guh *et al.* 2009; Dobbins *et al.* 2013). Total costs of healthcare utilization due to obesity are reported in Table 1.6 and amount to 443.4 million EUR. Figure 1.4 visually depicts the diseases that contribute the most to these costs. The largest portion of these costs is due to type II diabetes mellitus (91 million EUR), ischemic heart disease (83 million EUR) and osteoarthritis (74 million EUR), followed by dorsalgia (54 million EUR), hypertension (28 million EUR) and congestive heart failure (21 million EUR).

[9]PAFs are used in 5-year age groups when the data allows it. PAFs shown in Table 1.5 are aggregate, computed using the prevalence of obesity for men and women 15+ years.

Table 1.5: Comorbidities of obesity

Diagnosis	ICD-10 code	PAF (%) and 95% CI	
		women	men
Asthma	J45	18.0 (9.2, 27)	10.6 (3.7, 17.9)
Dorsalgia	M54	33.7 (26.3, 41)	33.4 (26.0, 40.7)
Type 2 diabetes mellitus	E11, E13, E14	76.2 (69.3, 81.8)	61.4 (55.7, 66.5)
Ischemic heart disease	I20–I25	37.1 (33.7, 40.5)	16.6 (12.4, 33.4)
Leukemia	C91–C95	8.2 (2.2, 14.4)	–
Malignant melanoma	C43, D03	–	6.7 (1.9, 11.7)
Stroke	I69.4, I64	12.1 (7.0, 17.2)	12.4 (8.4, 16.6)
Obesity	E66.0, E66.2, E66.8, E66.9, E65	100	100
Cholelithiasis and cholecystitis	K81, K80	27.0 (4.6, 50.0)	10.6 (1.1, 21.0)
Osteoarthritis	M15–M19	21.2 (19.8, 22.6)	46.9 (32.7, 59.9)
Pulmonary embolism	I26	41.3 (31.1, 51.1)	41.0 (30.8, 50.8)
Endometrial cancer	C54.1, C55, D07.0, D39.0	38.4 (34.9, 41.8)	–
Kidney cancer	C64, C65, C66, D30.0–D30.2	31.5 (28.1, 34.8)	18.5 (14.4, 22.5)
Breast cancer	D05, D24, D48.6, C50	3.5 (1.4, 5.8)	–
Pancreatic cancer	C25, D01.7, D13.6, D13.7	14.4 (4.6, 25.2)	26.3 (15.2, 37.7)
Colon cancer	C18, D12.0–D12.6	15.6 (12.7, 18.5)	20.8 (14.0, 27.8)
Ovarian cancer	C56, D27, D39.1	7.3 (5.3, 9.2)	–
Gallbladder cancer	C23, C24, D13.5	18.7 (8.2, 29.6)	11.5 (4.5, 19.0)
Congestive heart failure	I50	18.0 (1.9, 35.4)	17.9 (6.2, 30.5)
Hypertension	I10–I15	28.5 (14.2, 42.8)	18.9 (12.4, 25.5)

Source: Guh et al. *(2009), Dobbins* et al. *(2013). ICD-10 codes are taken from de Oliveira* et al. *(2015).*

Table 1.6: Healthcare utilization costs

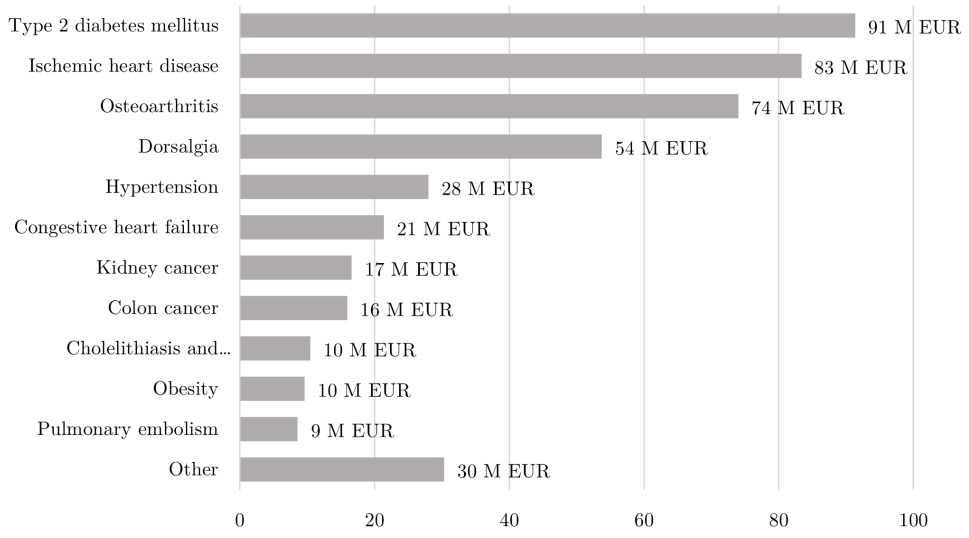
Diagnosis	**Costs (95% CI)**	**% of total costs**
Type 2 diabetes mellitus	91.3 (83.0, 98.5)	20.60%
Ischemic heart disease	83.4 (71.5, 114.7)	18.80%
Osteoarthritis	74.0 (57.0, 89.6)	16.69%
Dorsalgia	53.8 (41.9, 65.5)	12.12%
Hypertension	28.0 (15.7, 40.5)	6.32%
Congestive heart failure	21.4 (4.9, 39.3)	4.83%
Kidney cancer	16.6 (14.1, 19.0)	3.75%
Colon cancer	15.9 (11.7, 20.2)	3.59%
Cholelithiasis and cholecystitis	10.5 (1.6, 19.7)	2.36%
Obesity	9.6 (9.6, 9.6)	2.17%
Pulmonary embolism	8.6 (6.5, 10.6)	1.94%
Asthma	7.5 (3.4, 11.7)	1.68%
Breast cancer	5.4 (2.1, 8.9)	1.22%
Stroke	5.1 (3.2, 7.0)	1.14%
Pancreatic cancer	3.5 (1.7, 5.4)	0.78%
Endometrial cancer	3.2 (2.9, 3.5)	0.73%
Leukemia	2.5 (0.7, 4.4)	0.57%
Ovarian cancer	1.7 (1.2, 2.1)	0.38%
Gallbladder cancer	0.8 (0.3, 1.3)	0.18%
Malignant melanoma	0.7 (0.2, 1.2)	0.15%
Total	**443.4** (333.3, 573.0)	**100%**

Note: values are in millions EUR

Costs of pharmacotherapy

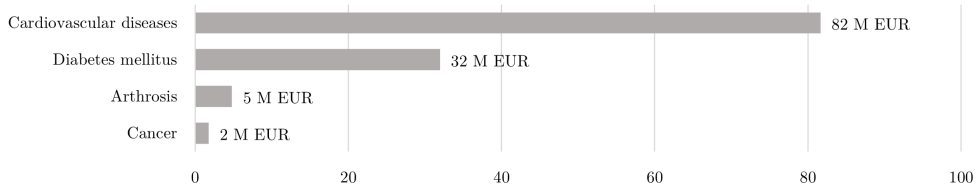
Figure 1.5 summarizes the costs of pharmacotherapy. Table 1.7 shows the ATC groups included in the study (Hodycová 2009; Dee *et al.* 2015) and the costs attributable to obesity. Drugs used in diabetes make up the largest part of pharmacotherapy costs (32 million EUR), followed by antithrombotic agents (23.2 million EUR) used for the cure of cardiovascular diseases and agents acting on the renin-angiotensin system (22.4 million EUR) used for the cure of cancer. Total pharmacotherapy costs attributable to obesity are 120.2 million EUR.

Figure 1.4: Healthcare utilization costs



Source: author's computations

Figure 1.5: Costs of pharmacotherapy



Source: author's computations

Table 1.7: Costs of pharmacotherapy

ATC classification	ATC code	Costs (95% CI)
For the cure of obesity		
Antiobesity preparations, excluding diet products	A08	0 (0, 0)[10]
For the cure of diabetes mellitus		
Drugs used in diabetes	A10	32.0 (29.0, 34.5)
For the cure of cardiovascular diseases		
Antithrombotic agents	B01	23.2 (14.2, 35.3)
Cardiac therapy	C01	3.3 (2.0, 5.0)
Antihypertensives	C02	3.7 (2.1, 5.4)
Diuretics	C03	4.0 (2.2, 5.7)
Beta blocking agents	C07	5.0 (2.8, 7.2)
Calcium channel blockers	C08	3.4 (1.9, 4.9)
Agents acting on the renin-angiotensin system	C09	22.4 (12.5, 32.3)
Lipid modifying agents	C10	16.8 (10.2, 25.6)
For the cure of cancer		
Antineoplastic agents	L01	1.8 (1.2, 2.3)
For the cure of arthrosis		
Anti-inflammatory and antirheumatic products	M01	4.8 (3.8, 5.9)
Total		**120.2** (82.0, 164.0)

Note: values are in millions EUR. ATC groups are chosen based on Hodycová (2009) and Dee et al. *(2015).*

1.6.2 Indirect costs

The indirect costs are visually summarized in Figure 1.6 and amount to 1025.3 million EUR.

Absenteeism

5.4 million productive days were lost due to obesity in 2018, of which 2.8 million days were attributable to men and 2.6 million days were attributable to women. Total costs of absenteeism are 360.2 million EUR (161.1 million EUR for women

[10]Pharmaceuticals used in the treatment of obesity are not covered by health insurance. An attempt was made to estimate these costs by contacting the State Institute for Drug Control, the Czech Statistical Office, the Ministry of Industry and Trade, and the Ministry of Health. However, none of these institutions collect data on pharmaceuticals that are not reimbursed by health insurance in the Czech Republic.

and 199.1 million EUR for men) and 314.5 million EUR (134.5 million EUR for women and 180.0 million EUR for men) after excluding the value of unpaid work. The results are summarized in Table 1.8.

Table 1.8: Results - absenteeism

	days lost	INCLUDING UNPAID WORK (millions EUR)	EXCLUDING UNPAID WORK (millions EUR)
Women (25-64)	2 616 984	161.1	134.5
Men (25-64)	2 818 935	199.1	180.0
Total	**5 435 919**	**360.2**	**314.5**

Presenteeism

The costs of presenteeism are summarized in Table 1.9. The baseline value for days lost in our model is 2 days of work lost, which is associated with costs of 274.9 million EUR and 240.5 million EUR after excluding the value of unpaid work. The costs of presenteeism for 1, 3 and 4 days amount to 137.4, 412.3 and 549.8 million EUR respectively (120.3, 360.8 and 481.1 million EUR, respectively, after excluding the value of unpaid work). The costs are larger for men than for women due to higher wages, higher prevalence of obesity among working men and higher employment rate in men.

Table 1.9: Results - presenteeism

Days lost	1 day	2 days	3 days	4 days
INCLUDING UNPAID WORK				
Women	55.9	111.8	167.7	223.7
Men	81.5	163.1	244.6	326.1
Total	**137.4**	**274.9**	**412.3**	**549.8**
EXCLUDING UNPAID WORK				
Women	46.6	93.2	139.8	186.4
Men	73.7	147.3	221.0	294.7
Total	**120.3**	**240.5**	**360.8**	**481.1**

Note: values are in millions EUR

Premature mortality

In 2018 women lost 72 608 years due to obesity, from which 2 947 years were productive years. Men lost in total 56 944 years due to obesity, from which 5 620 years were productive years. The reason why the productive years make such a small part of total years lost due to obesity is that most people die due to obesity-related diseases after retirement. In total, there were 12 505 obesity-related deaths (8 002 in women and 4 503 in men). On average, one person lost 10.4 years of life.

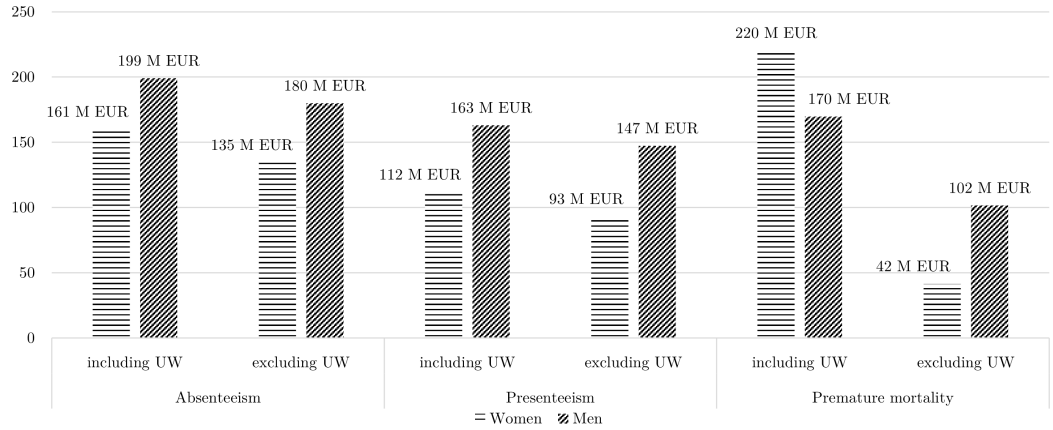
Using the discount rate of 3%, the costs of premature mortality due to obesity are 390.2 million EUR, including unpaid work. The costs are higher for women even though the amount of productive years lost is lower compared to men because women perform more hours of unpaid work. After excluding the unpaid work, the costs are 143.2 million EUR. Table 1.10 shows the results for different discount rates.

Table 1.10: Results - premature mortality

Discount rate	1%	3%	5%
INCLUDING UNPAID WORK			
Women	245.2	220.4	200.8
Men	193.0	169.8	151.7
Total	**438.2**	**390.2**	**352.5**
EXCLUDING UNPAID WORK			
Women	47.4	41.6	37.0
Men	114.9	101.6	91.1
Total	**162.3**	**143.2**	**128.1**

Note: values are in millions EUR

Figure 1.6: Summary of indirect costs



Source: author's computations; UW = unpaid work

1.6.3 Summary of results

Total costs of obesity in the Czech Republic for the year 2018 are summarized in Table 1.11. In total, they amount to 1.6 billion EUR[11], which corresponds to

[11]These figures reflect direct medical and indirect productivity costs only. Intangible costs such as pain, suffering, and quality-of-life losses are excluded from this total but are discussed in Appendix D.

0.8% of GDP in 2018 (Czech Statistical Office 2021). The indirect costs account for the majority of the total, reaching 1025.3 million EUR (64.5%), whereas the direct costs are 563.7 million EUR (35.5%), which represents 3.4% of total healthcare expenditures in 2018[12].

To provide a more intuitive perspective, this aggregate cost implies an average annual economic burden of approximately 697 EUR per obese adult, assuming an estimated 2.28 million obese individuals in the adult population in 2018. While the direct costs reflect actual healthcare expenditures (and thus a component of GDP), the indirect costs represent forgone economic output due to reduced productivity and premature mortality, i.e., potential GDP losses.

Table 1.11: Summary of results

	millions EUR	**% of total costs**
Direct costs	**563.7**	**35.5%**
Healthcare utilization	443.4	27.9%
Pharmacotherapy	120.2	7.6%
Indirect costs	**1025.3**	**64.5%**
Absenteeism	360.2	22.7%
Presenteeism	274.9	17.3%
Premature mortality	390.2	24.6%
TOTAL	**1588.9**	**100.0%**

1.6.4 Sensitivity analysis

Table 2.16 shows the change in costs attributable to obesity as the key parameters are varied. Total costs range between 1257.9 million EUR (-20.8% from baseline values) and 1993.7 million EUR (+25.5% from baseline values). The largest changes result from using the low and high relative risks values (95% CI). The overall costs decrease by 8.4% when the 2014 data on prevalence of obesity are used.

[12]Total healthcare costs in the Czech Republic were 430.9 billion CZK (16.8 billion EUR) in 2018 (Czech Statistical Office 2020).

Table 1.12: Sensitivity analysis

	Direct costs	% change	Indirect costs	% change	Total costs	% change
Baseline	563.7	–	1025.3	–	1588.9	–
Relative risks low values	415.3	-26.3%	842.6	-17.8%	1257.9	-20.8%
Relative risks high values	737	30.8%	1256.7	22.6%	1993.7	25.5%
Relative risks Dynamo project	505.9	-10.2%	939.8	-8.3%	1445.7	-9%
EHIS/EHES prevalence (2014)	510.3	-9.5%	945.9	-7.7%	1456.3	-8.4%
Discount rate 1%	563.7	0%	1073.3	4.7%	1636.9	3%
Discount rate 5%	563.7	0%	987.6	-3.7%	1551.2	-2.4%
Excluding unpaid work	563.7	0%	698.2	-31.9%	1261.9	-20.6%
Presenteeism 1 day	563.7	0%	887.8	-13.4%	1451.5	-8.7%
Presenteeism 3 days	563.7	0%	1162.7	13.4%	1726.4	8.7%
Presenteeism 4 days	563.7	0%	1300.2	26.8%	1863.8	17.3%

Note: values are in millions EUR

1.7 Discussion

The goal of this study was to calculate the direct and indirect costs of obesity in the Czech Republic in 2018. The resulting costs are equal to 1.6 billion EUR, which corresponds to 0.8% of GDP. These results likely represent a lower bound of the actual burden, as they are based on 2016 prevalence data, apply a conservative assumption for presenteeism, exclude intangible costs such as pain and suffering, and rely on the top-down method for attributing direct costs. The comparison of results across studies is complicated due to differences in methodological approach. A study from Germany, which is socio-economically similar to the Czech Republic, calculated the costs of overweight (BMI $\geq$ 25) in 2008 using a similar approach as 0.5% of GDP (Lehnert *et al.* 2015). This result is lower than ours mainly because it uses older data: both the prevalence of obesity and healthcare costs have increased largely since 2008.

A new OECD study estimated the burden of overweight and obesity (BMI $\geq$ 25) in 52 different countries to be 1.6–5.3% of GDP (OECD 2019b). The specific estimate for the Czech Republic is 4% of GDP, which is much higher than our result. This may have several reasons. Our study focuses purely on obesity (BMI $\geq$ 30), whereas the OECD study also includes overweight (i.e. BMI $\geq$ 25). The prevalence of overweight is much higher than of obesity in the Czech Republic: 70% for men and 55% for women. Furthermore, the OECD study uses different methodological approach (a microsimulation model vs. a country-level COI study) and data sources (often derived from other countries or studies), so the results are not directly comparable (see Box 1 for more details).

The direct costs of obesity are 563.7 million EUR, corresponding to 3.4% of healthcare expenditures. International studies report the impact of overweight and obesity on health expenditures to range between 2% and 7.9% (OECD 2019b). For comparison, a 2008 analysis from Germany, a country with a similar healthcare financing scheme, found that obesity-related health expenditures accounted for 3.27% of total healthcare spending (Lehnert *et al.* 2015). The indirect costs are 1025.3 million EUR, which exceeds previous estimates from the Czech Republic due to inclusion of presenteeism, unpaid work, use of gross salaries and rising prevalence of obesity.

Box 1: Comparison with OECD study on global burden of obesity

In 2019, OECD published a study estimating the burden of obesity in 52 countries, including the Czech Republic (OECD 2019b). The economic burden of overweight is estimated as 4% of GDP, which is much higher than our estimate of 0.8% of GDP. The OECD study and our research differ in many aspects. Here are the most important ones:

- The OECD study does not distinguish obesity from overweight. Our paper focuses purely on obesity (BMI≥30), whereas the OECD study evaluates the costs of overweight and obesity (BMI≥25). Even though pre-obesity, or overweight (BMI 25–30), is dangerous in a way that it often leads to obesity, it is associated with significantly lower risk of developing serious complications from comorbidities, as opposed to obesity.
- The methodology of the OECD study and our study is completely different. While the OECD study uses a microsimulation model, we perform a country-level COI study using the top-down approach and human capital approach. As stated in the OECD study, studies using the top-down approach usually provide a lower-bound estimate. The microsimulation model creates a synthetic population based on national demographic characteristics and risk factors from which life expectancy, disease prevalence and disability-adjusted life years are calculated. Different data sources are used in the OECD study, for example:
  - The data used for the estimation of healthcare utilization costs in the Czech Republic are estimated from the Netherlands data. In our study, we use the data from the Czech Republic, specifically from the General Health Insurance Fund. Additionally, each study computes the costs for a different set of diseases.
  - The data used in the estimation of costs related to unemployment and absenteeism come from the SHARE survey, which focuses on population 50-63 years old and the data are self-reported. In our study, we have data from the Institute of Health Information and Statistics (IHIS) of the Czech Republic for all the age groups.

  - The estimation of presenteeism related costs derives the days missed from absenteeism in a specific country using a study by Goetzel et al. (2004). From this study, the ratio of presenteeism:absenteeism missed days is derived for five health conditions: asthma, COPD, cardiovascular diseases, cancer and diabetes. The ratio is always larger than 1 (in three cases larger than 2), leading to very high estimated costs of presenteeism. In our study, we take a conservative approach based on a detailed literature review.
- The OECD study does not provide the specific amount of components of total costs for each country. Instead, it provides an aggregate result.
- We provide a very thorough sensitivity analysis where we vary the level of several key parameters of our analysis.

Cost-of-illness methodology is the most common measurement approach to calculate the burden of disease, but it has certain drawbacks. A variety of approaches within the COI methodology can be taken, which limits the comparability of results across studies. Additionally, it measures the value of individual's life only in terms of the production evaluated by average wage, ignoring other dimensions of illness and death, such as pain and lower quality of life (World Health Organization 2009). This narrow scope has been criticised in theoretical frameworks such as the Health Production Function (e.g., Harrington & Portney (1987)), which conceptualize the full social cost of illness as including not only lost earnings and treatment costs, but also averting behavior and disutility from illness. However, when performed with a clear explanation, COI studies represent an important analytic tool in public health policy (Segel 2006).

In this study, HCA is used to calculate the indirect costs of obesity. This method has been mainly criticised for assuming full employment in the economy, which relates mainly to the costs of absenteeism where every day the worker misses is regarded as lost production. However, the approach disregards the fact that the work can be made up by the worker after his/her return, or it can be done by his/her colleagues (World Health Organization 2009). The friction cost approach (FCA) solves this drawback and counts the productivity losses only for the time it takes to replace the absent worker. The HCA

is further criticised for evaluating the costs based on age- and gender-specific wages, implying that people earning lower wages are less valuable for the society. Willingness-to-pay approach mitigates this problem, however, it is not often employed as it requires extensive surveys of preferences (Segel 2006).

There are several limitations in our study, mainly related to availability of relevant data. Firstly, we use the data on prevalence of obesity from 2016, even though we calculate the costs of obesity in 2018 as no more recent data stratified by gender and age groups are available. The results of the EHES 2019[13] survey suggest increasing trends of obesity, which would imply even larger economic burden (NIPH 2022a).

Secondly, the relative risks used in the computation of population attributable fractions (PAFs) and the rate of presenteeism are based on foreign literature. RRs are specifically derived from the meta-analyses by Guh *et al.* (2009) and Dobbins *et al.* (2013), which synthesize a wide range of international evidence, primarily from the USA, Europe, and other high-income countries. These studies estimate the increased incidence of specific comorbidities among obese individuals relative to those with normal weight. Since the goal is to estimate healthcare costs and productivity losses resulting from increased disease prevalence and morbidity, using incidence-based relative risks is methodologically appropriate and consistent with standard practice in COI studies. For instance, a similar approach is endorsed in the WHO's Economics of Tobacco Toolkit (World Health Organization 2011), which states that morbidity-related relative risks can be used to attribute both medical costs and productivity losses to a risk factor. The same PAFs are also used to estimate the costs of premature mortality, under the assumption that the diseases contributing to excess morbidity are also responsible for a substantial share of obesity-related deaths. While this assumption introduces some uncertainty, it reflects prevailing practice in COI literature where cause-specific mortality data by risk factor are often unavailable. To address concerns about data transferability, a comprehensive sensitivity analysis is performed. Nonetheless, improving the accuracy of this analysis would ultimately require the collection of Czech-specific relative risks through dedicated epidemiological or longitudinal studies

Thirdly, the core results of this study do not account for intangible costs and disutility, that is, the non-monetary burdens of illness such as pain, suffering, and reduced quality of life. While these components are significant from both societal and individual perspectives, their inclusion in COI studies

[13]These data are stratified by gender and 10-year age groups.

remains relatively uncommon since the original development of the framework by Rice (1967). In theoretical models such as the Health Production Function (e.g., Harrington & Portney (1987)), disutility is recognized as a distinct and important component of the total economic burden of illness. Intangible costs and disutility are typically valued using methods such as WTP surveys or monetized QALYs and DALYs, which are well-established in welfare economics and health technology assessment. However, these approaches are not standard practice in cost-of-illness studies, which traditionally focus on direct and indirect costs measurable through healthcare and labor market data. To maintain consistency with the broader COI literature and focus the analysis on tangible economic impacts, these components are excluded from the main results. Nonetheless, to illustrate their potential magnitude, an indicative estimate is provided in Appendix D.

Another important limitation of the study relates to the measurement of absenteeism due to obesity-related diseases. The analysis uses data on "days of terminated cases of incapacity for work", which are recorded by the Czech Social Security Administration. These data capture instances where a physician officially declares a person temporarily unfit for work due to being ill, assigns an ICD-10 diagnosis code, and submits a standardized form. However, this dataset only includes individuals eligible for sickness benefits, primarily employees and some self-employed individuals who pay into the sickness insurance system. In 2018, approximately 92% of employed individuals[14] contributed to sickness insurance and were thus eligible for sick leave. Conversely, groups such as the unemployed, parents on parental leave, and some self-employed individuals are not eligible for sick leave and are not recorded in this dataset. While this may seem like a potential source of underestimation, these individuals are not engaged in paid employment and therefore their illness does not generate productivity losses in the traditional economic sense. Still, the restriction of the data to only those paying sickness insurance means that a small portion of potential productivity losses–especially among informal or unpaid work–might not be captured, and this should be considered when interpreting the results.

Finally, this study does not include the costs of informal caregivers or relatives related to obesity and its associated comorbidities. These costs can be substantial, especially for individuals with chronic or disabling conditions that require ongoing assistance with daily activities. However, reliable data on the

[14] 4 732 700 people paid the sickness benefits according to the Czech Statistical Office, while there were 5 147 thousands people employed according to Eurostat.

extent and value of caregiving specific to obesity-related diseases are not available in the Czech Republic. The absence of such data prevents the inclusion of caregiving costs in the analysis, potentially leading to an underestimation of the total societal burden. This limitation is consistent with most cost-of-illness studies, which often omit caregiving costs due to the difficulty in measuring unpaid care and the lack of standardized valuation methods. Nonetheless, it is important to recognize that caregiving represents a real economic and social cost, and its exclusion should be taken into account when interpreting the overall findings. Out-of-pocket expenditures are also not captured in the computations due to data limitations.

Our study demonstrates that the costs of obesity are considerable in the Czech Republic and comparable to the costs of smoking and alcohol consumption, which are estimated as 2.1 billion EUR (0.9% of GDP) in 2019 (Landovská 2024b) and 59.5 billion CZK (2.2 billion EUR, 1.2% of GDP) in 2016 (Chadimova *et al.* 2019), respectively. However, smoking and alcohol consumption have received more consistent attention in clinical practice and public health policy (Sturm 2002). Similarly as alcohol consumption and smoking, early onset of obesity or overweight significantly increases the probability of being obese in adulthood (Whitaker *et al.* 1997). This implies that obesity is a serious disease which should no longer be regarded as a lifestyle issue but needs to be recognised as a serious medical condition (Schmid *et al.* 2005).

1.8 Conclusion

The rising prevalence of obesity continues to place increasing pressure on healthcare systems and society, a trend further exacerbated by the COVID-19 pandemic. This study aimed to quantify the economic burden of obesity in the Czech Republic using data from 2018 and applying the COI approach. The total calculated costs amount to 1.6 billion EUR, corresponding to 0.8% of GDP. Of this, 563.7 million EUR (35.5%) are attributable to direct healthcare costs, and 1025.3 million EUR (64.5%) to indirect productivity losses. The direct costs alone represent 3.4% of total healthcare expenditures in 2018. Within the indirect costs, premature mortality accounts for the largest share (390.2 million EUR), followed by absenteeism (360.2 million EUR) and presenteeism (274.9 million EUR).

This is the first comprehensive country-level cost-of-illness study focused specifically on obesity in the Czech Republic. It includes multiple compo-

nents of both direct and indirect costs and provides results that are broadly comparable to similar studies for smoking and alcohol consumption. Given the ongoing increase in obesity prevalence, particularly among children and working-age adults, the associated economic burden is likely to rise. This underscores the urgency of implementing a coordinated set of prevention and intervention strategies to reduce obesity-related harm and alleviate long-term costs to the healthcare system.

It is important to note that the results reflect only the tangible, monetized components of the burden, namely healthcare and productivity costs, and do not include disutility or intangible costs such as pain, suffering, and reduced quality of life. These aspects, while excluded from the main analysis to ensure comparability with standard COI studies, are conceptually important and are discussed in Appendix D to provide a fuller picture of the societal impact of obesity.

Chapter 2

Economic Burden of Smoking in the Czech Republic[1]

2.1 Introduction

Smoking is a risk factor for many non-communicable diseases such as cancers, cardiovascular diseases, and respiratory diseases. Smoking leads not only to substantial healthcare costs but also to large productivity losses due to premature mortality and morbidity. Despite the broad evidence of the harmful effects of smoking, its prevalence remains very high in many countries (Reitsma *et al.* 2017). Globally, tobacco kills more than 8 million people each year and remains one of the leading causes of death. Furthermore, more than 1 million of these deaths are estimated to be caused by secondhand smoke exposure (World Health Organization 2023c).

This chapter aims to quantify the economic burden of smoking in the Czech Republic, focusing on direct healthcare expenditures and productivity losses. The Czech Republic ranked first in grams of tobacco consumed per capita among OECD countries in 2019 (OECD 2016), and it also ranked fourth in the number of cigarettes consumed per capita (15+ years), with 2194 cigarettes per person (The Tobacco Atlas 2019). In the Czech Republic, 16.2% of women and 23.8% of men were smokers, and 14.9% of women and 24.7% of men were former smokers in 2019 (IHIS 2020).

This analysis adopts a prevalence-based cost-of-illness approach, which views the costs of smoking as the sum of direct and indirect costs. This study is novel in being the most comprehensive, up-to-date, country-level cost-of-illness study,

[1]The findings of this chapter have been published in Landovská (2024b).

encompassing a broad range of direct and indirect cost components. However, it is important to note that this analysis does not quantify the costs of Secondhand Smoke (SHS) exposure due to data limitations. Specifically, while the health risks and mortality burden of SHS are well-documented, reliable national-level data on the number of individuals affected by SHS exposure in the Czech Republic are not available. As a result, this study focuses solely on the costs directly attributable to smokers themselves. Moreover, this analysis does not include intangible costs such as pain, suffering, and reduced quality of life in the core estimates. While these burdens represent an important part of the overall impact of smoking, they are excluded from the monetary estimates in this chapter[2] in order to ensure methodological consistency and comparability with the majority of cost-of-illness studies. This focus on tangible direct and indirect costs is in line with standard practice in the literature.. The analysis highlights the substantial burden of smoking in the Czech Republic, despite a recent decline in prevalence rates (NIPH 2022b).

This chapter builds upon the methodological foundation established in Chapter 1, as both analyses adopt the COI framework. In both cases, direct costs are estimated using the top-down approach, while indirect costs are computed using the HCA. The core computational procedures are thus consistent across the two chapters. However, important differences also arise due to data availability and the nature of the risk factors: smoking here versus obesity in Chapter 1. The chapters differ in the data sources used for estimating healthcare utilization and prevalence. Chapter 1 relies on aggregated data from the General Health Insurance Fund (GHIF), which are not disaggregated by gender or age. Due to access constraints, this chapter uses a different source, specifically from the Institute of Health Information and Statistics (IHIS), which offer more granular insights by age and gender. Similarly, smoking prevalence is based on the 2019 wave of the European Health Interview Survey (EHIS), chosen for its national representativeness and age stratification, which is crucial for precise cost estimates. Other data sources, such as those for wages, amount of paid and unpaid work, premature mortality, life expectancy, and retirement age, remain consistent with Chapter 1.

Another notable difference lies in the sensitivity analysis: Chapter 2 also applies the FCA to assess the robustness of indirect cost estimates, whereas Chapter 1 does not. This difference is due to the timing of the research. At the time Chapter 2 was written, the author had become familiar with both

[2]A more detailed discussion of intangible costs is provided in Appendix D.

the methodology and the required data for applying FCA, whereas this was not the case during the preparation of Chapter 1. Additionally, the FCA was not widely applied in COI studies examining the economic burden of obesity, but it has been applied in sensitivity analysis of some studies estimating the economic burden of smoking.

2.2 Literature Review

Studies quantifying the economic burden of smoking vary largely in methods used and cost components included, making them difficult to compare. Makate *et al.* (2020) provide a systematic review of tobacco cost-of-illness studies, including 63 papers published in 2008–2018. The majority of studies (89%) used the prevalence approach which estimates the smoking-related costs of all prevalent smokers over the course of the year. The studies typically focus on tangible costs of smoking, including the direct (healthcare) costs and indirect costs, mainly the productivity losses due to premature mortality and morbidity. The authors conclude that despite the variations in methods used, the costs of smoking are substantial.

Table B.1 in Appendix B summarizes the findings of relevant studies on the economic burden of smoking from various countries. All of the studies use the prevalence-based, cost-of-illness approach, and the individual country's economic burden of smoking ranges from 0.2% of GDP (Cher *et al.* 2017) to 4% of GDP (Koronaiou & Delipalla 2019). Globally, the burden of smoking in 2012 was estimated to be $1436 bn, representing 1.8% of global GDP (Goodchild *et al.* 2018). In 2009, the costs of smoking in European Union (27 member states) (EU27) alone were estimated at $544 bn, representing 4.4% of GDP (Jarvis *et al.* 2012). However, this study used the WTP approach which resulted in very large estimates.

Regarding the cost components included, most studies contain the direct (healthcare) costs due to smoking-related diseases and indirect costs, mainly the foregone earnings due to premature mortality and absenteeism. Several studies also include the costs of presenteeism (i.e. the reduced productivity while at work) (Lasocka *et al.* 2013; Shrestha *et al.* 2022; Cher *et al.* 2017; Whetton *et al.* 2019), the value of unpaid work (US Department of Health and Human Services 2014; Krueger *et al.* 2015), the intangible costs (Lievens *et al.* 2017; Whetton *et al.* 2019), the costs of SHS exposure (Koronaiou & Delipalla 2019; Sung *et al.* 2014; Whetton *et al.* 2019), the costs of smoking-caused fires

or environmental costs (Whetton *et al.* 2019). Studies including the costs of SHS exposure find that SHS exposure accounts for up to 10% of the total costs of smoking (Sung *et al.* 2014; Koronaiou & Delipalla 2019). An Australian study that included the intangible costs estimated that intangible costs made up nearly 62% of the total costs of smoking (Collins & Lapsley 2008).

Concerning the costs of presenteeism (i.e. the reduced productivity while at work), numerous studies have shown that employees who smoke have higher rates of presenteeism compared to non-smokers. In the US, Bunn *et al.* (2006) found that nonsmokers lose 42.8 hr per year, former smokers lose 56.0 hr per year and current smokers lose 76.5 hr per year due to presenteeism. Therefore, compared to nonsmokers, smokers lose 33.7 more hours and former smokers lose 13.2 more hours due to presenteeism. This corresponds to a presenteeism rate of 1.685% for current smokers and 0.66% for former smokers (Shrestha *et al.* 2022). Burton *et al.* (2005) estimate an excess loss of productivity of 2.8% for current smokers in the US. Berman *et al.* (2014) estimate the costs of a smoking employee in the US and use a conservative assumption of 1% loss of productivity due to smoking-related presenteeism. Additionally, they value the lost productivity due to smoking breaks based on the assumption that 2 cigarettes per day are smoked outside of sanctioned break times and it takes 15 min to smoke each cigarette. Based on these assumptions, the annual costs of smoking due to smoking breaks and presenteeism are estimated to be $3077.2 and $462, respectively. Whetton *et al.* (2019) estimate the costs of presenteeism based on a research of Medibank (Medibank 2011) which found that employed smokers lose annually 1.2 more days due to presenteeism in Australia, corresponding to a presenteeism rate of 0.48%.

The prevalence used for quantifying the costs of smoking is typically from a given year, with only a few studies using the lagged prevalence, accounting for a lag between initiating smoking and its impact on health and productivity (e.g. Bolin *et al.* (2011) uses a 5-year lag).

2.2.1 Previous findings from the Czech Republic

Several analyses of the economic burden of smoking have been conducted for the Czech Republic. A controversial early study commissioned by the tobacco company Philip Morris ČR a.s. and conducted by Arthur D. Little (Arthur D. Little International 2000) concluded that smoking generated a net economic benefit for the public budget, primarily through tax revenues and reduced ex-

penditures on pensions and healthcare resulting from shorter life expectancies. The reported net gain was €156 million in 1999. However, the study has been widely criticized for its flawed methodology and questionable assumptions (Ross 2004).

A more conventional analysis was carried out by Sovinová *et al.* (2007), who used the attributable risk approach to quantify the healthcare burden and mortality associated with smoking in 2002. According to their findings, hospital treatment costs for smoking-related diseases reached CZK 6.2 billion, and smoking was responsible for 20,550 deaths–representing 19% of all-cause mortality in the Czech Republic that year.

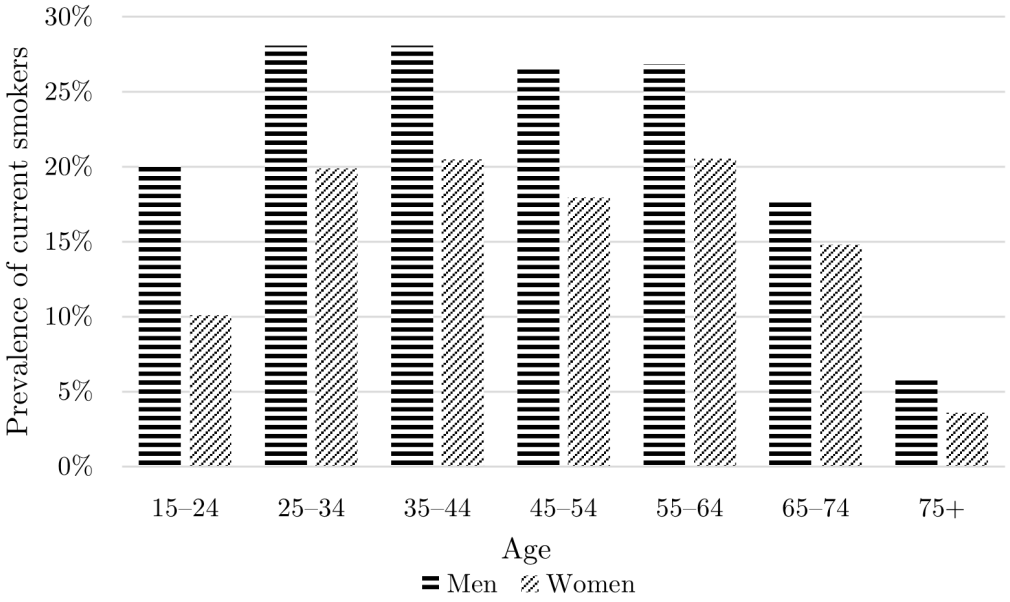
A broader cross-country study by Jarvis *et al.* (2012) assessed the burden of smoking in 27 EU countries. For the Czech Republic, the direct healthcare costs attributable to smoking were calculated at €351 million, corresponding to 3.2% of total health expenditures in 2009. The analysis also included indirect costs due to absenteeism (€16 million), long-term incapacity including early retirement (€19 million), and premature mortality (€11.4 billion). Notably, the costs of premature mortality were derived using the WTP approach, which generally produces substantially higher values than the human capital approach applied in this chapter.

2.3 Data

Table 2.3 summarizes the data used in the baseline model. The prevalence of smoking in the Czech Republic is taken from the newest EHIS (IHIS 2020), which was conducted in 2019. This survey provides data stratified by 10-year age groups (see Figure 2.1 for the prevalence of current smokers and Figure 2.2 for the prevalence of former smokers) which is desirable for an accurate estimate of the costs of smoking. The survey was coordinated by the IHIS in collaboration with the CSO and had nearly 8 thousand respondents (aged 15 years and older). According to the survey, the prevalence of smoking in the Czech Republic in 2019 was 16.2% for women and 23.8% for men; the prevalence of former smoking was 14.9% for women and 24.7% for men. For perinatal diseases, the prevalence of smoking among pregnant women is necessary. In the Czech Republic, only a small survey of 100 pregnant women in 2011 showed that 17% of pregnant women were daily smokers (Kolichová 2011).

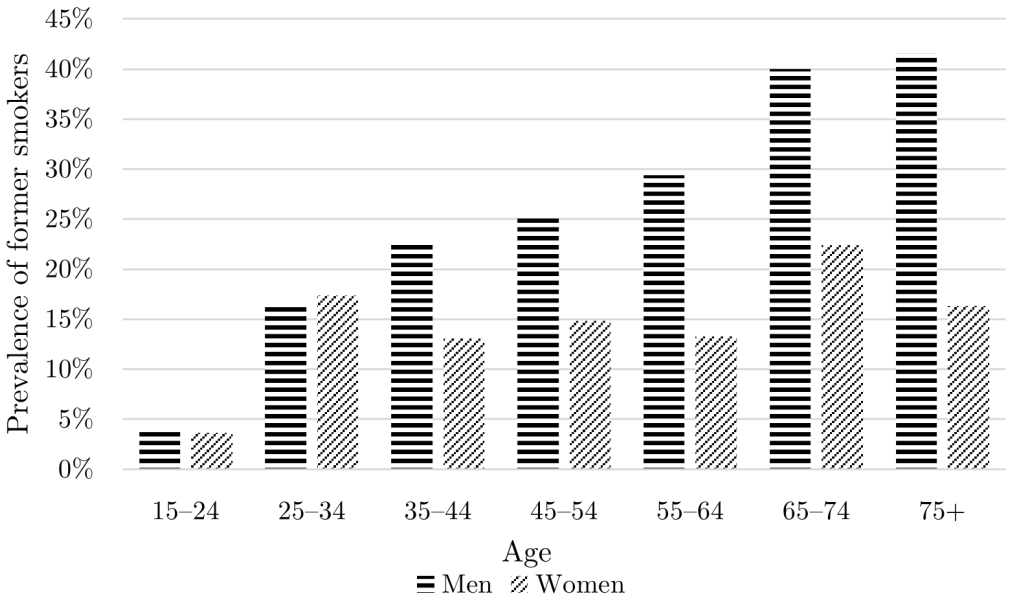
The RRs for adult mortality from smoking-related diseases used in this study are summarized in Table 2.1. These estimates are primarily based on the

Figure 2.1: Prevalence of smoking among current smokers (2019)



Source: EHIS (Institute of Health Information and Statistics 2020)

Figure 2.2: Prevalence of smoking among former smokers (2019)



Source: EHIS (Institute of Health Information and Statistics 2020)

Cancer Prevention Study II (CPS-II) and are taken from the 2014 US Surgeon General's Report (US Department of Health and Human Services 2014). The CPS-II cohort forms the empirical basis for most relative risk estimates used

in Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC) calculations. The models adjust for age, sex, race, and education, but do not fully control for behavioral confounders such as alcohol use or diet. However, Thun *et al.* (2000) have shown that adding these factors produces only minor adjustments to the risk estimates, suggesting limited bias due to omitted variables.

In addition to CPS-II data, relative risks for specific conditions are drawn from more recent and methodologically rigorous studies. For instance, Hannan *et al.* (2009) derive RRs for colorectal cancer from CPS-II by employing Cox proportional hazards models with time-varying covariates and adjusting for thirteen confounding factors, including BMI, diet, alcohol, physical activity, screening history, and hormone therapy. Ezzati *et al.* (2005) estimate smoking-attributable cancer mortality using CPS-II data as well, but include broader socioeconomic and dietary controls, offering robust site-specific RRs for global and regional cancer clusters. For ovarian cancer, Jordan *et al.* (2006) conduct a systematic review and meta-analysis using random-effects models and control for reproductive factors like parity and oral contraceptive use, which are important confounders in gynecological cancers.

These relative risks are used to compute the smoking-attributable fractions (Smoking-attributable Fractions (SAFs)) for each disease (see Section 2.4). Due to the lack of morbidity-specific relative risks in the Czech context, mortality-based RRs are used as proxies for morbidity risks, following a common practice in cost-of-illness studies[3] (Anh *et al.* 2016; Sung *et al.* 2014; Cher *et al.* 2017; Boachie *et al.* 2021). This approach assumes that the diseases associated with higher mortality among smokers, such as cancer, COPD, and cardiovascular disease, also impose a proportionally higher burden in terms of morbidity and healthcare costs. While this introduces a simplification, it provides a feasible way to estimate smoking-attributable morbidity in the absence of more detailed morbidity risk data.

The healthcare utilization costs by disease, age, and gender were provided by the IHIS from the National Registry of Reimbursed Health Services (IHIS 2019). These costs contain the costs of inpatient care, outpatient care, and aftercare. The detailed list of costs is available in Table 2.2. The costs of pre-

[3]This approach is in line with the WHO's guidance on estimating the economic costs of smoking. The WHO Economics of Tobacco Toolkit (2011) recommends using mortality-based relative risks as proxies for morbidity risks in the absence of morbidity-specific data. See World Health Organization (2011), p. 46 for healthcare costs and p. 62 for productivity losses.

Table 2.1: Relative risks by disease

Disease category (ICD–10 code)	Males		Females	
	Current smoker	Former smoker	Current smoker	Former smoker
Malignant neoplasms				
Lip, oral cavity, pharynx (C00–C14)	10.89	3.40	5.08	2.29
Esophagus (C15)	6.76	4.46	7.75	2.79
Stomach (C16)	1.96	1.47	1.36	1.32
Colorectum (C18–C20)	1.24	1.26	1.30	1.19
Liver (C22)	2.30	n/a	1.50	n/a
Pancreas (C25)	2.31	1.15	2.25	1.55
Larynx (C32)	14.60	6.34	13.02	5.16
Trachea, lung, bronchus (C33–C34)	23.26	8.70	12.69	4.53
Cervix uteri (C53)	n/a	n/a	1.59	1.14
Ovary (mucinous) (C56)	n/a	n/a	2.10	n/a
Kidney and renal pelvis (C64–C65)	2.72	1.73	1.29	1.05
Urinary bladder (C67)	3.27	2.09	2.22	1.89
Acute myeloid leukemia (C92.0)	1.86	1.33	1.13	1.38
Cardiovascular diseases				
Coronary heart disease (I20–I25)				
Persons 35–64 years of age	2.80	1.64	3.08	1.32
Persons $\geq$ 65 years of age	1.51	1.21	1.60	1.20
Other heart disease (I00–I09, I26–I28, I29–I51)	1.78	1.22	1.49	1.14
Cerebrovascular disease (I60–I69)				
Persons 35–64 years of age	3.27	1.04	4.00	1.30
Persons $\geq$ 65 years of age	1.63	1.04	1.49	1.03
Atherosclerosis (I70)	2.44	1.33	1.83	1.00
Aortic aneurysm (I71)	6.21	3.07	7.07	2.07
Other arterial disease (I72–I78)	2.07	1.01	2.17	1.12
Respiratory diseases				
Influenza, pneumonia (J10–J11, J12–J18)	1.75	1.36	2.17	1.10
Bronchitis, emphysema (J40–J42, J43)	17.10	15.64	12.04	11.77
Chronic airways obstruction (J44)	10.58	6.80	13.08	6.78
Diabetes mellitus (E10–E14)				
Persons 65–74 years of age	1.50	1.53	1.54	1.29
Persons $\geq$ 75 years of age	1.00	1.06	1.10	1.06
Perinatal diseases	**Boys**		**Girls**	
Short gestation/low birth weight (P07)	1.83	1.83	1.83	1.83
Respiratory distress syndrome (P22)	1.30	1.30	1.30	1.30
Other respiratory conditions in newborns (P23–P28)	1.41	1.41	1.41	1.41
Sudden infant death syndrome (R95)	2.29	2.29	2.29	2.29

Source: US Department of Health and Human Services (2014), Hannan et al. *(2009), Ezzati* et al. *(2005), Jordan* et al. *(2006), Gavin* et al. *(2001)*

scribed pharmacotherapy are not included in these costs as these are classified by ATC groups and not allocated to ICD-10 disease groups. Therefore, we include these costs separately. The overall costs for specific ATC groups in 2019 are available in the yearbook of the largest health insurance fund in the Czech Republic (the GHIF) (GHIF 2019) and are extrapolated to the whole population. The extrapolation coefficient is equal to 1.79 as there were 5.95 million people insured at GHIF in 2019 and Czech population was 10.67 million. The extrapolation of costs stems in multiplying the GHIF costs by the extrapolation coefficient, i.e.

$$Pharma\_C_{CZE,b} = Pharma\_C_{GHIF,b} \cdot 1.79, \tag{2.1}$$

where $Pharma\_C_{CZE,b}$ are the approximated pharmaceutical costs in Czech population for disease group b and $Pharma\_C_{GHIF,b}$ are the pharmaceutical costs of people insured at GHIF for disease group b. There are six more health insurance funds in the Czech Republic where the rest of the population is insured. We believe that the pharmacotherapy costs of GHIF are representative of the whole population so they can be extrapolated in this way.

Table 2.2: List of included healthcare costs

Inpatient care	Costs of treatment in hospitals
Outpatient care	Stomatologist care
	General practitioner care
	Gynaecologist care
	Rehabilitation care
	Diagnostic care
	Home care
	Special inpatient care
	Care in health facilities
	Spa care
	Transportation costs
	Emergency services
	Prescribed medical devices
Aftercare	Sanatoriums (independent)
	Hospitals for long term illness (independent)
	Sickbeds (independent)
	Hospices (independent)

Source: IHIS

The number of workdays missed and the number of deaths due to each smoking-associated disease in 2019, stratified by gender and 10-year age groups, was obtained from the IHIS, specifically from the Information System Incapacity for Work (IHIS 2019) and Information System Deaths (IHIS 2019a), respectively.

To value the smoking-related lost productivity, both paid and unpaid work are considered. Paid work is valued by gross wage from the CSO Structure of Earnings Survey (Czech Statistical Office 2019), stratified by gender and age groups. According to a survey by the CAS (CAS 2016), men spend 2 hours a day and women spend 3 hours a day doing unpaid work. This unpaid work is valued by the average wage of cleaning services in 2019 taken from the Average Earnings Information System (AEIS 2019), which is 107 CZK/hour (approximately €4.3).

The number of employed people in the age group 35-64 years is taken from the CSO (Czech Statistical Office 2019). We assume that people work on average 225 days a year (there are on average 250 working days a year, and employers typically have 25 days of vacation). We assume employers work 8

hours a day. Life expectancy by gender and age groups is taken from the CSO Life Tables (Czech Statistical Office 2018a). The survival rate in the Czech Republic in 2019 is taken from WHO Life tables (World Health Organization 2023a).

Table 2.3: Data sources

Measure	Data source	Year
Direct costs		
Healthcare utilization	National Registry of Reimbursed Health Services (IHIS 2019)	2019
Pharmaceuticals	General Health Insurance Fund (GHIF 2019)	2019
Indirect costs		
Absenteeism	Information System Incapacity for Work (IHIS 2018)	2019
Presenteeism	Bunn *et al.* (2006)	2006
Premature mortality	Information System Deaths (IHIS 2018)	2019
Other sources		
Prevalence of smoking	European Health Interview Survey (IHIS 2020)	2019
Prevalence of smoking among pregnant women	Kolichová (2011)	2011
Relative risks	US Department of Health and Human Services (2014)	2014
	Hannan *et al.* (2009)	2009
	Ezzati *et al.* (2005)	2005
	Jordan *et al.* (2006)	2006
	Gavin *et al.* (2001)	2001
Gross salary	Czech Statistical Office (CSO 2019)	2019
Unpaid work	Czech Academy of Sciences (CAS 2016)	2015
Value of unpaid work	Average Earnings Information System (AEIS 2019)	2019
Employed population	Czech Statistical Office (CSO 2019)	2019
Life expectancy	Czech Statistical Office (CSO 2018)	2019
Survival rate	World Health Organisation (WHO 2023a)	2019
Fires (damage, deaths)	Fire Rescue Service of the Czech Republic (2020)	2019

2.4 Methodology

This chapter applies the prevalence-based cost-of-illness approach, which quantifies the economic burden of all existing cases of smoking within a given year, including the present value of lost earnings due to premature mortality. The analysis focuses on the tangible costs of smoking, specifically direct healthcare expenditures and productivity losses, corresponding to the first two components of the Health Production Function framework: medical care and foregone earnings.

Direct costs are computed using the attributable-risk approach (also referred to as the top-down method), which allocates a share of total healthcare spending to smoking-related diseases based on relative risks and smoking

prevalence. Indirect costs are calculated using the human capital approach, capturing productivity losses resulting from absenteeism, presenteeism, and premature mortality. The total burden reflects the additional costs borne by society compared to a counterfactual scenario in which smoking is absent for an extended period.

All costs are calculated for the population aged 35 and over[4] in the year 2019. Values are expressed in euros, converted from Czech koruna (CZK) using the average 2019 exchange rate provided by the European Central Bank.

2.4.1 Direct costs

Healthcare utilization costs

Based on the literature, we identify the diseases whose likelihood increases when a person is smoking and find the associated relative risk (RR). Relative risk measures how much more likely will (current or former) smoker have a given disease compared to a never-smoker. $RR_d = \frac{r_1}{r_2}$, where r_1 is the probability of disease d in the smoking population (current or former) and r_2 is the probability of disease d in the never-smoking population. Using the prevalence of current and former smokers in the Czech Republic from 2019, we compute the smoking-attributable fractions according to the following formulas:

$$SAF_{CS,dag} = \frac{p_{CS,ag} \cdot (RR_{CS,d} - 1)}{p_{NS,ag} + p_{CS,ag} \cdot RR_{CS,d} + p_{FS,ag} \cdot RR_{FS,d}} \tag{2.2}$$

$$SAF_{FS,dag} = \frac{p_{FS,ag} \cdot (RR_{FS,d} - 1)}{p_{NS,ag} + p_{CS,ag} \cdot RR_{CS,d} + p_{FS,ag} \cdot RR_{FS,d}} \tag{2.3}$$

using $p_{NS,ag} + p_{CS,ag} + p_{FS,ag} = 1$

$$\begin{aligned} SAF_{dag} = SAF_{CS,dag} + SAF_{FS,dag} = \\ \frac{p_{NS,ag} + p_{CS,ag} \cdot RR_{CS,d} + p_{FS,ag} \cdot RR_{FS,d} - 1}{p_{NS,ag} + p_{CS,ag} \cdot RR_{CS,d} + p_{FS,ag} \cdot RR_{FS,d}}, \end{aligned} \tag{2.4}$$

where $SAF_{CS,dag}$ and $SAF_{FS,dag}$ are the smoking-attributable fractions of current smokers and former smokers, respectively, for disease d, age group a, and gender g; $p_{CS,ag}$, $p_{FS,ag}$ and $p_{NS,ag}$ are the prevalence rates of current smokers, former smokers, and never-smokers for age group a and gender g, and $RR_{CS,d}$ and $RR_{FS,d}$ are the relative risks for current and former smokers, respectively,

[4]This age threshold is used because the relative risks employed to derive the smoking-attributable fractions are defined for individuals aged 35 and above.

for disease d (see Table 2.1)[5]. SAF_{dag} is the overall smoking-attributable fraction for a given disease d, age group a, and gender g.

The healthcare utilization costs attributable to smoking (HC) are computed as:

$$HC = \sum_{d} \sum_{a} \sum_{g} SAF_{dag} \cdot C_{dag}, \tag{2.5}$$

where C_{dag} are the healthcare utilization costs for disease d, age group a, and gender g. These costs are obtained from the IHIS (IHIS 2019) and contain all the medical costs of patients who had the disease d identified by the ICD-10 code as the main diagnosis, i.e. it was the main cause of receiving the treatment.

Costs of pharmacotherapy

The healthcare utilization costs do not contain the costs of prescribed medicaments as these are classified by the ATC groups. We include these costs separately by identifying several ATC groups related to smoking-associated diseases based on two studies (Hodycová 2009; Dee *et al.* 2015). Specifically, we incorporate the costs of prescribed medicaments for the cure of cardiovascular diseases, cancers, and respiratory diseases. The specific ATC groups are available in Table 2.7. Due to data limitation (the costs of ATC groups are aggregate for all ages and genders), we estimate the pharmaceutical costs (PC) attributable to smoking as:

$$PC = \sum_{b} Pharma\_C_b \cdot SAF_b \cdot a, \tag{2.6}$$

where $Pharma\_C_b$ are the costs for the specific ATC group b and SAF_b is the smoking-attributable fraction for this ATC group, which is obtained as the average of SAFs of the diseases included in this group as specified in Table 3 in the Supplementary information. a is an adjustment parameter for the age group 35+ years, derived based on the healthcare utilization costs.

2.4.2 Indirect costs

The indirect costs are valued according to the HCA, which calculates the present value of productivity losses due to mortality and morbidity caused by smoking-related diseases. Production losses were considered for the population under the age of 65 years. We include the costs of absenteeism, presenteeism, and premature mortality. The lost productivity is valued by paid work (PW_{ag}) and

[5]RRs are not available for age groups for diseases identified by the ICD-10 codes.

unpaid work (UW_g), monetized by average gross salary (GS_{ag}) and the average wage of houseworker[6] (W_{HW}), respectively:

$$P_{ag} = PW_{ag} \cdot GS_{ag} + UW_g \cdot W_{HW}, \tag{2.7}$$

where P_{ag} refers to age- (a) and gender- (g) specific evaluation of productivity lost. SAF_{dag} specific for disease (d), age (a), and gender (g) is used to determine the smoking-attributable productivity lost because the data are stratified by 10-year age groups and genders.

Absenteeism

Absenteeism refers to missed days at work due to smoking-associated diseases. The number of days absent due to each smoking-related disease d, age group a, and gender g (DA_{dag}) is obtained from the IHIS (Institute of Health Information and Statistics 2018b). The number of days absent due to smoking for each disease d, age a, and gender g ($DA_{dag}^{smoking}$) are computed as:

$$DA_{dag}^{smoking} = DA_{dag} \cdot SAF_{dag}. \tag{2.8}$$

The indirect costs of these days missed is obtained from

$$IC^{absenteeism} = \sum_d \sum_a \sum_g DA_{dag}^{smoking} \cdot P_{ag}, \tag{2.9}$$

where P_{ag} is the valuation of lost time in paid and unpaid work as specified in Equation 2.7.

Presenteeism

Presenteeism refers to lost productivity while being present at work. To the best of our knowledge, there is no research about smoking-attributable presenteeism in the Czech Republic. However, research from other countries has shown that compared to non-smokers, smokers have higher rates of presenteeism and also spend time on smoking breaks (Berman *et al.* 2014; Burton *et al.* 2005; Bunn *et al.* 2006). We thus include the costs of presenteeism and overtake the assumption based on research from the U.S. that current smokers have 1.685% and former smokers have 0.66% higher rate of presenteeism compared to non-smokers (Bunn *et al.* 2006).

[6]Wage of household worker is not available by gender/age group.

The costs of presenteeism ($IC^{presenteeism}$) are computed as:

$$IC^{presenteeism} = Pres\_rate \cdot N_{wd} \cdot N_{wh} \cdot W_{hourly} \cdot E \cdot p_{working\_age} \tag{2.10}$$

where $Pres\_rate$ is the presenteeism rate in percent, N_{wd} and N_{wh} are the number of working days per year (assume 225) and working hours per day (assume 8), respectively, W_{hourly} is the average hourly wage, E is the number of employed people and $p_{working\_age}$ is the prevalence of smoking in the working-age population.

Premature mortality

To quantify the productivity losses due to premature mortality, we use the data on number of deaths due to each smoking-related disease, stratified by gender and age group. The present value of future lost earnings (NPV) is computed using a discount rate (i) which is 3% in the baseline scenario. Following standard practice, we assume a 2.5% productivity growth rate (v), which is the average GDP growth rate in Czechia from 2010-2019.

$$NPV = \sum_{t=0}^{n} \frac{FV(1+v)^t}{(1+i)^t}, \tag{2.11}$$

where FV stands for future value and t is the number of years lost.

The indirect costs due to smoking-related premature mortality ($IC^{mortality}$) are computed as:

$$\begin{aligned} IC^{mortality} = & \sum_{d} \sum_{a} \sum_{g} SAF_{dag} \cdot M_{dag} \cdot SR_{ag} \cdot ER_{ag} \\ & \cdot \left(0.5 \cdot P_{ag} + \sum_{t=1}^{ret-1} \frac{P_{ag}}{(1+i)^t} + \sum_{t=ret}^{exp} \frac{UW_g \cdot W_{HW}}{(1+i)^t} \right) \end{aligned} \tag{2.12}$$

where M_{dag} stands for disease-, age- and gender- specific number of deaths, SR_{ag} is the survival rate and ER_{ag} is the employment rate for age group a and gender g. Only half of the productivity is accounted for in the first year ($t = 0$) to correct for different occurrences of death during the year. The productive years (i.e. before retirement age ret, which is 61 years for women and 63 years for men) are monetized by the value of paid and unpaid work, while the years after retirement until life expectancy age exp are monetized by the value of unpaid work only. Only part of these costs are attributable to smoking, which is computed using the SAF_{dag}.

Smoking-caused fires

To quantify the costs associated with smoking-caused fires, we follow a similar approach as for premature mortality due to smoking-related diseases. To obtain the number of fires, the damage caused and the number of deaths, we use the data from the Statistical yearbook of Fire Rescue Service of the Czech Republic (2020). Fatalities are valued using the average gross wage for men, assuming a loss of 15 years of life per death (based on the average years of life lost due to smoking-related causes). A discount rate of 3% and an earnings growth rate of 2.5% are applied. This method captures productivity losses due to premature mortality resulting from fire incidents initiated by smoking.

Sensitivity analysis

In sensitivity analysis, we change the following parameters:

- Relative risks and their 95% confidence intervals for selected cancers are taken from other sources (see Table 2.4)[7],
- unpaid work is excluded in indirect costs,
- presenteeism rate is changed: 1% and 2.8% for current smokers and 0% and 1% for former smokers (Berman *et al.* 2014; Burton *et al.* 2005),
- growth rate is set to 0% (i.e. no growth rate), 1% and 4%,
- the discount rate is set to 1% and 5%,
- overall results are recomputed using all-cause Hazard Ratios (HRs) from a study focusing on three Eastern European countries (Russia, Belarus, and Hungary) (Stefler *et al.* 2018) (more information is provided in Box 2),
- and indirect costs (absenteeism and premature mortality) are computed using the FCA.

[7] RRs for former smokers and other diseases are the same as in the baseline scenario.

Table 2.4: Sensitivity analysis – relative risks of smoking-associated diseases

Disease category (ICD-10 code)	Males (95% CI)	Females (95% CI)	Source
Stomach (C16)	2.2 (1.8, 2.7)	1.5 (1.2, 1.9)	Ezzati *et al.* (2005)
Colorectum (C18–C20)	1.2 (1, 1.6)	1.3 (1, 1.7)	Hannan *et al.* (2009)
Liver (C22)	2.3 (1.5, 3.8)	1.5 (0.8, 2.7)	Ezzati *et al.* (2005)
Pancreas (C25)	2.2 (1.7, 2.8)	2.2 (1.8, 2.8)	Ezzati *et al.* (2005)
Lung (C33–C34)	21.3 (17.7, 25.6)	12.5 (10.9, 14.3)	Ezzati *et al.* (2005)
Cervix (C53)	–	1.5 (0.9, 2.6)	Ezzati *et al.* (2005)
Ovary (mucinous) (C56)	–	2.1 (1.7, 2.7)	Jordan *et al.* (2006)
Kidney (C64–C66, C68)	2.5 (1.8, 3.6)	1.5 (1, 2.1)	Ezzati *et al.* (2005)
Urinary bladder (C67)	3 (2.1, 4.3)	2.4 (1.5, 4.1)	Ezzati *et al.* (2005)
Acute myeloid leukaemia (C92.0)	1.89 (1.3, 2.9)	1.3 (0.8, 1.8)	Ezzati *et al.* (2005)

Box 2: Sensitivity analysis based on study in Eastern European countries

Due to the unavailability of RRs for particular diseases in Czechia, we perform another sensitivity analysis using HRs from Eastern European countries (Russia, Belarus, and Hungary) for the most recent period available in the study (2006-2013) (Stefler *et al.* 2018). For more details, please refer to the study. These HRs are used to proxy the relative risks (RRs). It is necessary to note that HRs and RRs are not the same measures and the literature suggests not to use them interchangeably (Stare & Boulch 2016). The HRs (see Table 2.5) and overall prevalence of smoking in the Czech Republic are used to compute the all-cause SAFs:

$$SAF_{CS,g} = \frac{p_{CS,g} \cdot (HR_{CS,g} - 1)}{(HR_{CS,g} - 1) + 1}, \tag{2.13}$$

where $SAF_{CS,g}$ is the all-cause smoking-attributable fraction for current smokers (CS) and gender g, $p_{CS,g}$ is the prevalence of current smokers in the Czech Republic for gender g and $HR_{CS,g}$ is the all-cause hazard ratio of mortality for current smokers vs. non-smokers from Stefler et al. (Stefler *et al.* 2018). We use this $SAF_{CS,g}$ to compute the direct costs (costs of healthcare utilization and costs of pharmacotherapy) and indirect costs (costs of absenteeism and premature mortality) by multiplying the $SAF_{CS,g}$ by the overall costs due to all diseases which were obtained from the Institute of Health Information and Statistics. The costs of

presenteeism are calculated as in the baseline scenario because we do not use the RRs in the computations. We compare these results with costs of smoking computed using all-cause RRs for the US taken from the US Surgeon General's report (US Department of Health and Human Services 2014).

Table 2.5: Hazard ratios from Eastern European countries

	Country	**Men**	**Women**
Model 1	Russia	1.97	1.71
	Belarus	1.82	1.64
	Hungary	2.05	2.15
Model 2	Russia	1.58	1.40
	Belarus	1.57	1.67
	Hungary	1.82	2.01

Source: Stefler et al. *(2018)*

2.4.3 Friction cost approach

The friction cost approach is an alternative way to measure the indirect costs of disease in COI studies. Some experts argue that HCA overestimates the indirect costs and propose using FCA, which focuses on short-term replacement costs and is used only in 5–8% of COI studies (Pike & Grosse 2018). Contrary to HCA which estimates the value of potentially lost production (until retirement age) as a consequence of a disease, the FCA estimates the value of lost production only during the so-called friction period, which is the time it takes to replace the worker and restore initial production (Koopmanschap *et al.* 1995). The length of the friction period depends on the average vacancy duration, which depends on the level of unemployment and on the efficiency of the labour market in matching labour demand and supply (Koopmanschap *et al.* 1995). In studies using the FCA to measure indirect costs, the friction period varies from 6 weeks to 6 months (Pike & Grosse 2018). Additionally, the FCA assumes that a reduction of annual labour time causes a less than proportional decrease in labour productivity per year. The proponents of this method suggest using the elasticity for annual labour time versus labour productivity between 0.6 and

0.9, using $e = 0.8$ as a baseline assumption (Koopmanschap *et al.* 1995). Compared to HCA, FCA leads to lower cost estimates. The ratio of HCA:FCA costs varies widely in literature and it ranges from 1.3 to 72.34, depending e.g. on the length of the friction period considered (longer friction period minimizes the difference in the two approaches), or the costs included (the ratio is higher for studies that include the indirect costs of premature mortality) (Pike & Grosse 2018).

Because there is insufficient background on the quantification of presenteeism costs with FCA (Kigozi *et al.* 2017), we apply the FCA on the costs of absenteeism and premature mortality only. The FCA focuses on paid work only as it assumes no welfare loss or cost when someone who is unemployed becomes employed (Pike & Grosse 2018). The length of the friction period for the Czech Republic is assumed to be 146 days (approximately 4.8 months) (Hanly *et al.* 2020). The costs of absenteeism are computed analogically as in HCA (Equation 2.8 and Equation 2.9) with different data on the number of days absent due to disease for each age group and gender. The number of days absent considered in FCA are only those during the friction period, i.e. 146 days at maximum. Furthermore, the elasticity for annual labour time versus labour productivity of 0.8 is applied to the costs of absenteeism (Koopmanschap *et al.* 1995). The indirect costs of mortality using the FCA are calculated as:

$$IC_{FCA}^{mortality} = \sum_{d} \sum_{a} \sum_{g} SAF_{dag} \cdot M_{dag} \cdot SR_{ag} \cdot ER_{ag} \cdot PW_{ag} \cdot GS_{ag} \cdot F \cdot e, \quad (2.14)$$

where M_{dag} stands for disease-, age- and gender- specific number of deaths, SR_{ag} is the survival rate and ER_{ag} is the employment rate for age group a and gender g. $PW_{ag} \cdot GS_{ag}$ is the value of paid work during the friction period F (146 days), and e is the elasticity for annual labour time vs. labour productivity (0.8). SAF_{dag} ensures that only part of these costs are attributable to smoking.

2.5 Results

2.5.1 Direct costs

Healthcare utilization costs

The medical costs attributable to smoking-related diseases amount to 317.1 mil EUR, with 85 mil incurred by women and 232.1 mil by men. Table 2.6 shows that the main drivers of costs were heart diseases, trachea, lung and bronchus

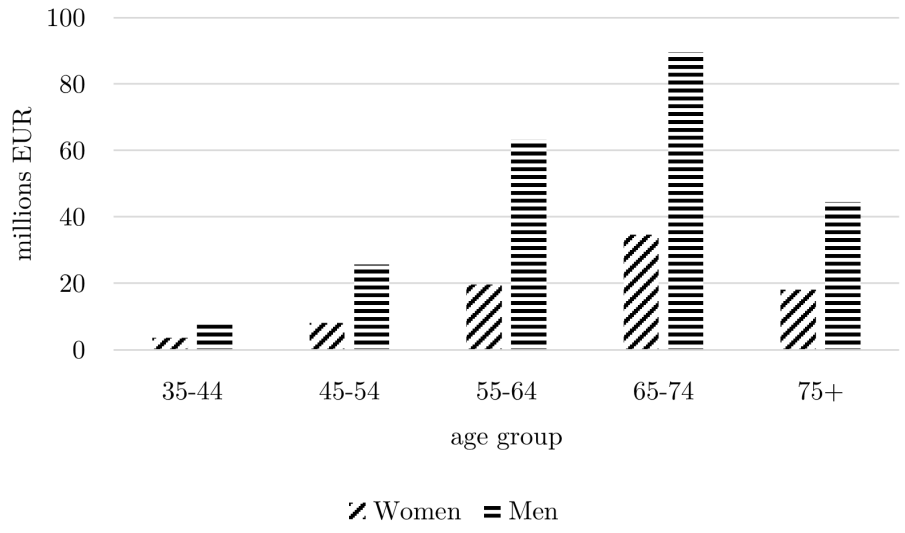
cancers, chronic airways obstruction, and cerebrovascular disease. Figure 2.3 displays the distribution of medical costs across age groups. For both men and women, the highest costs are observed in the 65–74 age group.

Table 2.6: Results – healthcare utilization costs

	Women	Men	Total
Other heart disease (I00–I09, I26–I28, I29–I51)	11.9	41.0	52.9
Coronary heart disease (I20–I25)	9.9	40.9	50.8
Trachea, lung, bronchus (C33–C34)	14.6	25.1	39.6
Chronic airways obstruction (J44)	13.8	21.8	35.6
Cerebrovascular disease (I60–I69)	7.6	13.3	20.9
Atherosclerosis (I70)	2.1	13.3	15.4
Lip, oral cavity, pharynx (C00–C14)	2.9	11.9	14.8
Kidney and renal pelvis (C64–C65)	0.6	11.3	11.9
Aortic aneurysm (I71)	2.0	8.2	10.3
Other	19.6	45.3	64.9
Total	**85.0**	**232.1**	**317.1**

Values are in millions EUR

Figure 2.3: Healthcare utilization costs by age



Source: author's computations

Costs of pharmacotherapy

The costs of pharmacotherapy due to smoking-related diseases are summarized in Table 2.7 and amount to 219.8 mil EUR. The largest costs are attributable to drugs for obstructive airway diseases used in the cure of respiratory diseases and antithrombotic agents used in the cure of cardiovascular diseases.

Table 2.7: Results – costs of pharmacotherapy

Disease group	ATC classification	ATC code	Costs
Cardiovascular diseases	Antithrombotic agents	B01	41.0
	Cardiac therapy	C01	5.0
	Diuretics	C03	4.9
	Beta blocking agents	C07	6.1
	Calcium channel blockers	C08	4.0
	Agents acting on the renin-angiotensin system	C09	29.0
	Lipid modifying agents	C10	26.5
Diabetes mellitus	Drugs used in diabetes	A10	27.5
Malignant neoplasms	Antineoplastic agents	L01	5.1
Respiratory diseases	Drugs for obstructive airway diseases	R03	70.6
Total			**219.8**

Values are in millions EUR

2.5.2 Indirect costs

Absenteeism

1.3 million working days (0.4 million in women and 0.95 million in men) were lost due to smoking-attributable absenteeism in 2019 (see Table 2.8). The largest amount of days lost were due to coronary heart disease (296 292 days lost), influenza and pneumonia (192 230 days lost) and cerebrovascular disease (172 335 days lost). Total costs of absenteeism amount to 144.8 mil EUR when unpaid work is included (38.6 mil for women and 106.2 mil for men) and 126.1 mil EUR when unpaid work is excluded (31.5 mil in women and 94.6 mil in men), as shown in Table 2.9. Figure 2.4 displays the age distribution of days lost. In both men and women, the highest number of days lost occurs in the 55–64 age group.

Table 2.8: Results – absenteeism (days lost by disease)

Disease group	Men	Women	Total
Coronary heart disease (I20–I25)	252063	44229	296292
Influenza, pneumonia (J10–J11, J12–J18)	96561	95669	192230
Cerebrovascular disease (I60–I69)	113478	58857	172335
Chronic airways obstruction (J44)	68488	38307	106795
Other heart disease (I00–I09, I26–I28, I29–I51)	85645	19010	104655
Trachea, lung, bronchus (C33–C34)	60574	29678	90252
Lip, oral cavity, pharynx (C00–C14)	56855	14383	71238
Bronchitis, emphysema (J40J–42, J43)	34431	34019	68450
Atherosclerosis (I70)	38838	3885	42723
Kidney and renal pelvis (C64–C65)	27951	1576	29528
Colorectum (C18–C20)	20771	7550	28321
Urinary bladder (C67)	20011	2529	22540
Esophagus (C15)	18701	1670	20371
Other	61569	34199	95768
Total	**955936**	**385561**	**1341497**

Table 2.9: Results – absenteeism (costs)

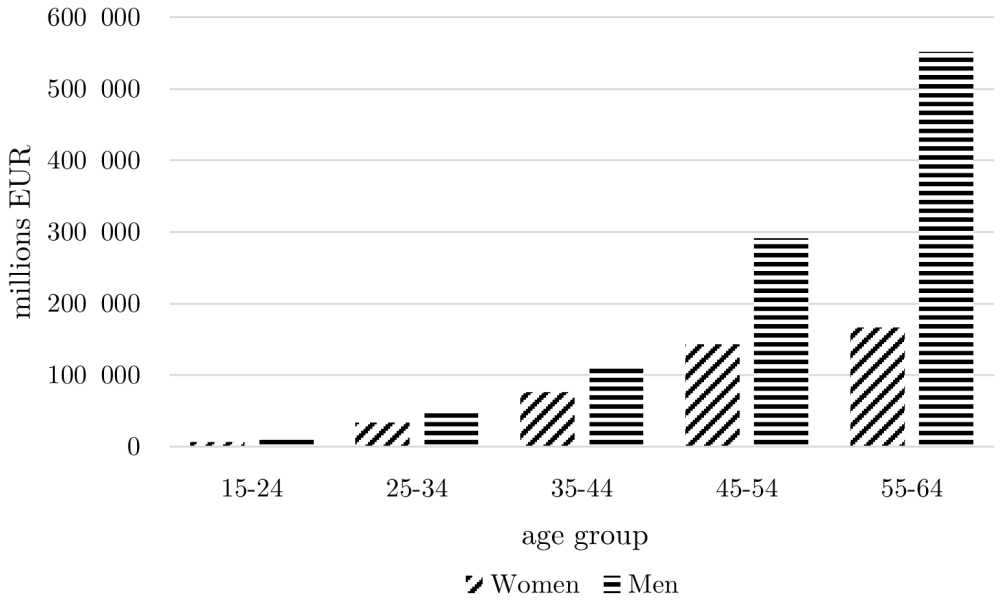
	days lost	INCLUDING UNPAID WORK	EXCLUDING UNPAID WORK
Women	385561	38.6	31.5
Men	955936	106.2	94.6
Total	**1341497**	**144.8**	**126.1**

Values are in millions EUR

Presenteeism

Table 2.10 summarizes the costs of presenteeism. In the baseline scenario where we assume the presenteeism rate of 1.69% among current smokers and 0.66% among former smokers, the value lost due to presenteeism is 101.8 mil EUR

Figure 2.4: Absenteeism costs by age



Source: author's computations

among currently smoking women, 173.3 mil EUR among currently smoking men, 27.8 mil EUR among formerly smoking women and 63.5 mil EUR among formerly smoking men. In total, the costs of presenteeism are 366.3 mil EUR when unpaid work is included and 317.5 mil EUR when unpaid work is excluded.

Table 2.10: Results – presenteeism (costs)

	INCLUDING UNPAID WORK		
Current smokers			
Presenteeism rate	1.00%	1.69%	2.80%
Women	60.4	101.8	169.1
Men	102.9	173.3	288.0
Former smokers			
Presenteeism rate	0.00%	0.66%	1.00%
Women	0	27.8	42.1
Men	0	63.5	96.2
Total	**163.2**	**366.3**	**595.4**
	EXCLUDING UNPAID WORK		
Current smokers			
Presenteeism rate	1.00%	1.69%	2.80%
Women	49.4	83.2	138.2
Men	91.9	154.9	257.4
Former smokers			
Presenteeism rate	0.00%	0.66%	1.00%
Women	0	22.7	34.4
Men	0	56.7	86.0
Total	**141.3**	**317.5**	**515.9**

Values are in millions EUR

Premature mortality

In 2019, there were in total 36 853 deaths in men and 34 761 deaths in women due to smoking-attributable diseases. Out of this, 10 536 deaths in men and 4 359 deaths in women were directly attributable to smoking. These deaths are equivalent to 158 363 years lost in men and 68 735 years lost in women. Most of the years lost due to premature mortality were in post-productive age. Specifically, 18 247 productive years were lost due to smoking in men and 4 072 productive years were lost due to smoking in women. On average, a smokers lost 15.3 years of life due to dying prematurely.

The overall productivity losses due to smoking-related premature mortality

are 1 062.5 mil EUR in the baseline scenario (assuming a 2.5% growth rate and 3% discount rate). When unpaid work is excluded, the productivity losses are 694 mil EUR. Table 2.11 and Table 2.12 show the variability of value lost when different assumptions on discount rates and growth rates are taken.

Table 2.11: Results – premature mortality (different discount rates)

	INCLUDING UNPAID WORK		
discount rate	1%	3%	5%
Women	284.2	233.5	197.3
Men	953.2	829.0	733.0
Total	**1237.4**	**1062.5**	**930.3**
	EXCLUDING UNPAID WORK		
discount rate	1%	3%	5%
Women	93.5	85.2	78.4
Men	681.3	608.8	550.4
Total	**774.7**	**694.0**	**628.8**

Values are in millions EUR.

Growth rate is set to 2.5% in the baseline scenario.

Table 2.12: Results – premature mortality (different growth rates)

INCLUDING UNPAID WORK				
growth rate	0%	1%	2.5%	4%
Women	121.2	156.8	233.5	352.6
Men	456.1	578.3	829.0	1194.5
Total	**577.2**	**735.1**	**1062.5**	**1547.0**
EXCLUDING UNPAID WORK				
growth rate	0%	1%	2.5%	4%
Women	67.3	82.5	85.2	152.4
Men	351.7	437.7	608.8	847.8
Total	**419.0**	**520.2**	**694.0**	**1000.2**

Values are in millions EUR.

Discount rate is set to 3% as in the baseline scenario.

Smoking-caused fires

According to the Statistical Yearbook of the Fire Rescue Service of the Czech Republic, there were 1,402 smoking-caused fires in 2019, representing 7.45% of all fires. These fires caused total material damage of €2.37 million (2.74% of total fire-related damages). Additionally, 15 deaths were attributed to smoking-related fires. Using the methodology described above, the economic loss associated with the 15 fatalities amounts to €6.4 million. In total, the combined costs of smoking-caused fires reach €8.8 million.

2.5.3 Friction cost approach

Table 2.13 summarizes the costs of smoking due to absenteeism and premature mortality using the friction cost approach. 460 540 working days were lost due to absenteeism and their value was 43 mil EUR. The value of lost productivity due to premature mortality was 20.3 mil EUR. In total, the indirect costs of smoking using the FCA amount to 63.4 mil EUR. As mentioned in Section 2.4, these estimates do not include the value of unpaid work.

The HCA:FCA ratios are reported in Table 2.14. The costs computed using the HCA are 12.9 times higher compared to the costs computed using the FCA,

which is driven mainly by the costs of premature mortality.

Computing the costs of smoking using the FCA leads to overall costs equal to 600.3 mil EUR, corresponding to 0.27% of GDP in 2019.

Table 2.13: Results – absenteeism and premature mortality using FCA

	Absenteeism		Premature mortality
	days lost	FCA costs	FCA costs
Women	171728	14.0	3.9
Men	288811	29.0	16.4
Total	**460540**	**43.0**	**20.3**

Values are in millions EUR

Table 2.14: Results – HCA:FCA ratio

	HCA	FCA	HCA:FCA ratio
Absenteeism	144.8	43.0	2.9
Premature mortality	1062.5	20.3	34.1
Total	**1207.3**	**63.4**	**12.9**

Values are in millions EUR

2.5.4 Summary of results

In the baseline scenario, the total costs of smoking in the Czech Republic in 2019 amount to 2 119.3 mil EUR[8], corresponding to 0.94% of GDP. Table 2.15 summarizes the direct and indirect costs of smoking. 25% percent of costs were direct and 75% were indirect. The direct costs correspond to 2.9% of total health expenditures in the Czech Republic in 2019. Within indirect costs, the largest component is premature mortality, accounting for 50% of total costs.

To offer a more intuitive perspective, this aggregate cost implies an average annual economic burden of approximately 761 EUR per adult ever-smoker (current and former) aged 35 and above. While the analysis does not differentiate costs by smoking status, this figure reflects the average tangible cost per

[8]These figures reflect direct medical and indirect productivity costs only. Intangible costs such as pain, suffering, and quality-of-life losses are excluded from this total but are discussed in Appendix D.

individual to whom the model attributes a portion of the burden. As with the obesity results, the direct costs reflect actual GDP expenditure, whereas the indirect costs represent foregone or potential GDP due to productivity losses.

When the FCA is used in the computation of indirect costs, the total costs of smoking decrease to 600.3 mil EUR, corresponding to 0.27% of GDP in 2019.

Table 2.15: Summary of results

	millions EUR	% of total costs
Direct costs	**537.0**	**25.34%**
Healthcare utilization	317.1	14.96%
Pharmacotherapy	219.8	10.37%
Indirect costs	**1582.4**	**74.66%**
Absenteeism	144.8	6.83%
Presenteeism	366.3	17.29%
Premature mortality	1062.5	50.13%
Fires	8.8	0.41%
Total	**2119.3**	**100%**

Values are in millions EUR.

2.5.5 Sensitivity analysis

The results of sensitivity analysis are summarized in Table 2.16. The results are the most sensitive to the growth rate used in the computation of costs due to premature mortality. Using zero growth rate results in a 23.3% decrease in total costs of smoking, whereas using growth rates of 1% and 4% leads to a 15.9% decrease and a 22.4% increase in total costs, respectively. Excluding unpaid work in indirect costs leads to a 21.0% drop in overall costs. On the other hand, using relative risks from different sources and their 95% confidence interval does not affect the results much.

The costs of smoking using all-cause SAF are much lower in the US when compared with our baseline analysis, mainly because these costs do not include the costs of former smokers. The results are sensitive to the model used (using model 1, the results are quite robust while using model 2, the costs are up to 20% lower than in the US) and specific country (results computed based on SAF from Hungary are the least sensitive in both models).

Table 2.16: Sensitivity analysis

	Direct costs	% change	Indirect costs	% change	Total costs	% change
Baseline	537.0	–	1582.4	–	2119.3	–
Alternative RRs (low)	515.6	-4.0%	1509.6	-4.6%	2025.3	-4.4%
Alternative RRs (medium)	529.2	-1.5%	1569.4	-0.8%	2098.6	-1.0%
Alternative RRs (high)	543.9	1.3%	1641.2	3.7%	2185.1	3.1%
Excluding unpaid work	537.0	0%	1137.5	-28.1%	1674.5	-21.0%
Presenteeism lower bound	537.0	0%	1370.5	-13.4%	1907.5	-10.0%
Presenteeism upper bound	537.0	0%	1802.6	13.9%	2339.6	10.4%
Growth rate 0%	537.0	0%	1088.4	-31.2%	1625.3	-23.3%
Growth rate 1%	537.0	0%	1246.2	-21.2%	1783.2	-15.9%
Growth rate 4%	537.0	0%	2058.2	30.1%	2595.1	22.4%
Discount rate 1%	537.0	0%	1748.6	10.5%	2285.5	7.8%
Discount rate 5%	537.0	0%	1441.4	-8.9%	1978.4	-6.6%
all-cause SAF US	275.6	–	683.5	–	959.1	–
all-cause SAF Russia, model 1	211.1	-23.4%	701.9	2.7%	913.0	-4.8%
all-cause SAF Belarus, model 1	194.8	-29.3%	675.1	-1.2%	869.9	-9.3%
all-cause SAF Hungary, model 1	235.9	-14.4%	732.0	7.1%	967.9	0.9%
all-cause SAF Russia, model 2	153.6	-44.3%	612.7	-10.4%	766.3	-20.1%
all-cause SAF Belarus, model 2	170.7	-38.1%	629.1	-8%	799.8	-16.6%
all-cause SAF Hungary, model 2	212.5	-22.9%	693.2	1.4%	905.7	-5.6%

Values are in millions EUR.

2.6 Discussion

This study aimed to quantify the economic burden of smoking in the Czech Republic in 2019, which amounts to 2119.3 mil EUR, corresponding to 0.94% of GDP. These costs are calculated using a prevalence-based cost-of-illness framework, applying the attributable risk method for direct costs and the human capital approach for indirect costs. We do not include intangible costs in the analysis, or the costs of SHS exposure. While SHS exposure is a well-documented public health concern, national-level data on the number of individuals affected by SHS exposure in the Czech Republic are not available. This study focuses solely on the costs directly attributable to smokers themselves. These exclusions imply that the results represent a lower bound of the true social burden of smoking, as only the first two components of the Health Production Function, namely medical care and productivity losses, are included in the analysis. Comparability across cost-of-illness studies is limited due to differing methodologies and cost components. To illustrate this variation, we apply the friction

cost approach (FCA) as an alternative method for valuing productivity losses. The resulting costs using this approach are much lower and are equal to 63.4 mil EUR.

The direct costs, which consist of healthcare utilization costs and the costs of pharmacotherapy, amount to 537.0 mil EUR, corresponding to 2.89% of health expenditures in 2019. This proportion is similar to the estimate in EU27 countries where the direct costs of smoking represent 2.9% of total health expenditures (Jarvis *et al.* 2012). The indirect costs, which consist of the costs of absenteeism, presenteeism, premature mortality and the costs associated with smoking-related fires, amount to 1582.4 mil EUR, representing 74.7% of total costs. Premature mortality is the main driver of indirect costs, accounting for 1062.5 mil EUR. In studies estimating both direct and indirect costs of smoking, it is common that the indirect costs exceed the direct costs (see Table B.1 in Appendix B). A majority of the total costs (74%) are attributable to men, primarily due to higher smoking prevalence and wage levels among male individuals.

Comparing our results with previous estimates in the Czech Republic, our results are overall higher. This is because we took a more comprehensive approach, incorporating several groups of costs that had not been included in previous studies, including more diseases and using different methods. Focusing on the specific groups of costs, Sovinová *et al.* (2007) estimated the costs of hospital treatment due to smoking-related diseases as 6.2 bn CZK (201.3 mil EUR) and 20 550 deaths caused by smoking in 2002. This is comparable to our calculated healthcare utilization costs of 317.1 mil EUR, and nearly 15 000 deaths lost. The difference in results is mainly caused by a higher prevalence of smoking in 2002[9] and different data sources used in the estimation of direct costs. Jarvis *et al.* (2012) estimated the direct costs of smoking for six main disease groups in 2009 in the Czech Republic to be 351 mil EUR (3.2% of health expenditures), which is comparable to our estimate. However, this estimate is derived based on expenditure statistics from England, Germany, and the Netherlands. The reported costs of absenteeism and long-term incapacity in Jarvis *et al.* (2012) are lower, which is caused by using different methods, i.e. valuing the productivity losses by average wage and using aggregate data on a national level. The estimate on mortality equal to 11.4 bn EUR is very

[9]The prevalence of smoking among men was assumed to be 37.2% for current smokers and 22.9% for former smokers. The prevalence of smoking among women was assumed to be 20.4% for current smokers and 14.4% for former smokers.

large which is caused by valuing the life year lost by €52000. Compared to earlier studies, the present analysis incorporates more comprehensive and granular data, stratified by smoking-related diseases, age groups, and gender. The costs of smoking are comparable to the costs of alcohol or obesity in the Czech Republic, which are estimated as 59.5 bn CZK/2170 mil EUR (1.2% of GDP) in 2016 (Chadimova *et al.* 2019) and 40.8 bn CZK/1586 mil EUR (0.8% of GDP) in 2018 (Landovská & Karbanová 2023), respectively.

This study has several limitations, mainly related to data availability. First, the relative risks and rates of presenteeism used in the model come from U.S. studies, which have a limited relevance in the Czech Republic. However, these data are commonly used in other analyses of the economic burden of smoking.

Second, smoking-attributable fractions (SAFs) were calculated using relative risks (RRs) and the prevalence of smoking in the population. Due to the lack of morbidity-specific RRs in the Czech context—particularly for estimating direct healthcare costs and costs of absenteeism—RRs for mortality were used as proxies. This follows a common practice in COI studies and WHO's guidance on estimating the economic costs of smoking, who recommends using mortality-based relative risks as proxies for morbidity risks in the absence of morbidity-specific data. This is based on the assumption that increased mortality risk generally reflects a broader increase in disease burden and severity, especially for conditions such as cancer, COPD, and cardiovascular diseases. While this method enables a practical estimation of the attributable burden in the absence of more detailed data, it may introduce some degree of bias, as the relationship between mortality and morbidity is not necessarily proportional across diseases.

The SAF formula reflects the proportion of disease burden that can be attributed to a specific risk factor. For example, if 50% of the population smokes, there are no former smokers, and the relative risk of death among smokers is 10, the resulting SAF is 82%. This means that 82% of deaths from the selected diseases could be prevented if smokers had the same mortality risk as non-smokers. The SAF does not represent the share of smokers who die, but rather the share of the total population-level burden that is attributable to the elevated risk from smoking. This reflects the counterfactual logic of population attributable risk and should be interpreted accordingly. More discussion on the interpretation and appropriate end-points of the SAF is provided in Section B.2.

Third, the results largely depend on data assumptions that we take, e.g.

the discount rate, the growth rate, etc. We thus perform a thorough sensitivity analysis varying several key parameters of the model to show the variability of results to different assumptions.

Fourth, the results presented in this chapter do not include the costs of SHS exposure or intangible costs, which implies that the total economic burden of smoking is likely underestimated. SHS exposure is associated with substantial health risks and corresponding costs, but due to the absence of reliable population-level data on exposure and outcomes in the Czech Republic, these costs could not be robustly quantified within the scope of this study. Intangible costs, such as pain, suffering, and reduced quality of life, are also excluded from the core estimates. These costs are highly relevant from a societal and welfare-economic perspective, and are typically valued using methods such as WTP or QALYs. However, intangible costs are still rarely included in cost-of-illness studies, which have historically focused on direct healthcare costs and productivity losses. To ensure comparability with the existing COI literature and maintain a consistent methodological focus, this chapter follows the conventional approach of excluding intangible costs from the main results. Nonetheless, an illustrative estimate of the potential magnitude of intangible costs associated with smoking is provided in Appendix D to offer a broader perspective on the societal burden.

Fifth, due to data restrictions, we do not consider the costs of informal caregivers or relatives who take care of patients with smoking-related illnesses, or out-of-pocket expenditures. The resulting figure of 2 119.3 mil EUR should therefore be interpreted as a lower-bound approximation of the total social burden of smoking, reflecting only the tangible costs associated with medical care and productivity loss.

Another important limitation of the study concerns the measurement of absenteeism due to smoking-related illnesses. The analysis relies on data from the Czech Social Security Administration, which record days of work incapacity certified by a physician and linked to a smoking-related diagnosis. However, these records cover only individuals eligible for sickness insurance, mainly employees and some self-employed persons. Groups such as the unemployed, those on parental leave, and self-employed individuals not contributing to sickness insurance are excluded. While these individuals are typically not in paid employment and thus do not generate productivity losses in the conventional economic sense, some informal or unpaid work losses may remain unaccounted for and should be acknowledged when interpreting the results.

Regarding the methodology, we use the human capital approach in the baseline scenario to estimate the indirect costs of smoking. The HCA fully considers the costs of absenteeism, presenteeism, and premature mortality. However, this method has been criticized for overestimating the costs. The alternative approach, the friction cost method, has thus been used as an alternative approach to compute the indirect costs of smoking. This method only considers 80% of the costs in the friction period, which is 146 days in the Czech Republic. The proponents of this method argue that it provides more realistic estimates of the productivity costs. On the other hand, it has been criticized for having no theoretical underpinning and for treating leisure time as having no value (Brouwer & Koopmanschap 2005). Furthermore, only costs of absenteeism and premature mortality are calculated using the FCA, excluding the costs of presenteeism, due to insufficient background on the estimation of presenteeism costs with FCA. The resulting indirect costs amount to 63.4 mil EUR. The HCA:FCA ratio is equal to 12.9, which is in accordance with other studies that estimated the indirect costs using both methods (Pike & Grosse 2018). In COI studies focused on the economic burden of smoking, the friction cost approach is rarely used. Neubauer *et al.* (2006) use the FCA in sensitivity analysis, concluding that compared to HCA, the overall costs of smoking are 85% lower. In the present study, overall costs of smoking using the FCA are 72.8% lower than the costs computed using the HCA, which is comparable.

A well-known challenge in estimating the economic burden of smoking is the lag between exposure and the onset of disease. Many smoking-related illnesses, particularly cancers, cardiovascular diseases, and chronic respiratory conditions, develop only after prolonged periods of use and may manifest decades after smoking initiation. This long latency complicates the interpretation of cost estimates, especially when relying on current smoking prevalence, which may not accurately reflect the historical exposure of those currently experiencing smoking-attributable illness.

A widely used approach to address this issue is the method developed by Peto *et al.* (1992), which constructs a synthetic estimate of cumulative smoking exposure called the Smoking Impact Ratio (SIR). This measure uses lung cancer mortality rates as a proxy for lifetime smoking intensity by comparing observed lung cancer mortality in the study population with reference rates from smokers and never-smokers in a well-characterized cohort (typically the Cancer Prevention Study II). The SIR has been used by e.g. Whetton *et al.* (2019) to estimate the burden of diseases with long lag periods more accurately

than would be possible using current prevalence alone.

While conceptually appealing, implementing the SIR approach requires detailed mortality data disaggregated by smoking status, which are not available for the Czech Republic at the required level of granularity. In light of these data constraints and in line with established practice in the cost-of-illness literature, this study adopts the more common approach of using current smoking prevalence and mortality-based relative risks to estimate SAFs. Although this method does not explicitly account for long-term exposure histories, it remains widely used in settings where individual-level or retrospective smoking data are not accessible.

It is important to emphasize that this approach may lead to underestimation of the true burden. Smoking prevalence in the Czech Republic has declined in recent decades, meaning that individuals currently suffering from smoking-related diseases likely began smoking under different conditions and at higher population prevalence levels. As such, the estimates presented here should be interpreted as conservative, reflecting only the portion of the burden that can be attributed based on currently available data.

2.7 Conclusion

This chapter quantifies the economic burden of smoking in the Czech Republic in 2019 among individuals aged 35 and older. The total costs amount to 2 119.3 mil EUR, corresponding to 0.94% of GDP. The analysis is based on a prevalence-based cost-of-illness framework, combining the attributable risk method for direct costs and the human capital approach for indirect costs. Direct costs, which include healthcare utilization and pharmacotherapy, amount to 537.0 mil EUR. Indirect costs, comprising absenteeism, presenteeism, and premature mortality, reach 1 582.4 mil EUR.

These results reflect only the first two components of the Health Production Function, i.e. medical care expenditures and productivity losses. Intangible costs, including disutility from pain, suffering, and reduced quality of life, are not included in the main calculations. As such, the total presented here should be interpreted as a lower-bound approximation of the full societal burden of smoking. An illustrative discussion of intangible costs is provided separately in Appendix D.

Despite several limitations, this study offers the most comprehensive and up-to-date analysis of the costs of smoking in the Czech Republic. The findings

confirm that smoking imposes a substantial burden on the economy, comparable in scale to the costs of alcohol consumption (Chadimova *et al.* 2019) and obesity (Landovská & Karbanová 2023). Smoking is not only a major public health concern due to its causal link with numerous diseases, but also a driver of significant productivity losses across the working-age population.

Although smoking prevalence has declined in recent decades, it remains a persistent societal challenge. According to OECD statistics, the Czech Republic ranked first in grams of tobacco consumed per capita among OECD countries in 2019 (OECD 2016). These findings reinforce the case for sustained investment in evidence-based tobacco control strategies aimed at reducing smoking-related harms and alleviating future cost burdens on the healthcare system and the economy as a whole.

Chapter 3

Business cycle sensitivity of Statutory Health Insurance: Evidence from the Czech Republic[1]

3.1 Introduction

Achieving sustainable financing of the healthcare sector is challenging in the context of aging populations and health and economic shocks. Adequate funding is essential to ensure the long-term sustainability of healthcare systems and to maintain the availability and affordability of health services. One key aspect of financial stability is the extent to which healthcare financing mechanisms are sensitive to economic fluctuations. In this chapter, we focus on the business cycle sensitivity of SHI schemes, which are one of the two dominant healthcare financing models in the European Union, alongside general taxation-based systems (Jakubowski *et al.* 1998). The term "business cycle sensitivity" refers to the responsiveness of SHI revenues to macroeconomic conditions, particularly fluctuations in employment, wages, and overall economic activity. Since SHI schemes are predominantly funded through payroll-based contributions, economic downturns may lead to revenue shortfalls, potentially challenging the financial sustainability of healthcare provision. Although the relationship between the business cycle and healthcare system revenues has been frequently discussed, it has not yet been systematically quantified for either SHI (Bismarck model) or general taxation (Beveridge model) schemes. This study aims to fill this gap by providing empirical evidence on the extent to which SHI revenues

[1]The findings of this chapter have been published in Landovská (2024a).

fluctuate with economic conditions and assessing the implications for healthcare system resilience.

The financial crisis of 2008 has pointed out the weaknesses of healthcare financing in many countries, especially in those where financing relies to some extent on employer-employee contributions, have large out-of-pocket payments, or have a significant part of population paying Private Health Insurance (PHI). During the crisis, healthcare systems' revenues decreased significantly in Greece, Lithuania and Estonia, which are countries where financing relies on the SHI scheme (WHO 2017; WHO 2008; WHO 2015). Each country responded in its own way to handle the consequences. In Greece, public expenditures were significantly reduced (WHO 2015); in Lithuania, the loss was covered by increasing state contributions thanks to counter-cyclical mechanism that had been already implemented (WHO 2015); and in Estonia, financial reserves were used along with budgetary cuts (Habicht *et al.* 2019).

The aim of this chapter is to quantify the effect of the business cycle on SHI revenues of the Czech health care system, which has not been done before. Our data span from Q1 2000 to Q4 2017 and cover the period around the financial crisis of 2008 which was a shock that started the debate about resilience of healthcare systems. We test eight different business cycle indicators, with nominal GDP being evaluated as the most sensitive indicator of business cycle for Czech health insurance funds' revenues. We examine the cyclicality of total revenues and the main revenue components (employer-employee contributions and state contributions).

While we lack systematic evidence on the effect of business cycle on the revenues, the effect on the expenditures has been examined by several studies (Liang & Tussing 2019; Arze del Granado *et al.* 2013; Keegan *et al.* 2013; Portela & Thomas 2013). They suggest that cyclicality depends on country's level of development: pro-cyclical pattern has been found in developing countries (Liang & Tussing 2019) and counter-cyclical pattern has been found in developed countries (Arze del Granado *et al.* 2013). A study in the EU27 countries has shown that healthcare expenditures (both public and private) displayed counter-cyclical patterns at least initially after the 2008 financial crisis (Keegan *et al.* 2013). Another study in the EU27 countries found a decrease in healthcare expenditure and an increase in pharmaceutical expenditure and in the number of medical consultations during the crisis (Portela & Thomas 2013). A systematic review of studies about the impact of the crisis on the use of healthcare services in Europe showed that austerity measures lead to

increasing inequality in access to healthcare and the crisis contributed to rising unmet needs, reduction in hospital beds and privatization of services (Recio *et al.* 2022).

3.2 Review of the Czech healthcare system

The SHI system in the Czech Republic provides universal coverage to all residents, achieving nearly 100% population coverage. The Ministry of Health serves as the main administrative and regulatory authority. SHI covers a broad range of benefits, including inpatient and outpatient care, prescription pharmaceuticals, and certain dental procedures. Due to this extensive coverage, voluntary health insurance plays only a marginal role in the system (Bryndová *et al.* 2023).

In 2019, public sources accounted for 81.5% of total health expenditure[2]. The primary funding source is SHI contributions, which are collected from four groups: (i) employers and employees, (ii) economically inactive individuals as defined by law[3], (iii) self-employed individuals, and (iv) individuals without taxable income. The largest share of SHI revenue (91.4% in 2019) comes from the first two groups. Notably, economically inactive individuals from the second group, such as students, pensioners, and the unemployed, constitute just over half of the population and are exempt from paying SHI contributions. Instead, the state finances their contributions on their behalf (Bryndová *et al.* 2023). In the analyses, I focus on the total revenues of SHI, and then I separately analyse the two main components of the SHI revenues: (i) employer-employee contributions, and (ii) contributions from economically inactive individuals, which are referred to as "state insured" further in the text. The contributions made by state on behalf of state insured individuals are referred to as "state contributions".

The SHI contributions are collected monthly from employers and employees, the self-employed, and individuals without taxable income who do not qualify for any of the state insured groups. SHI contributions are legally set at 13.5% of pre-tax monthly wages for employees, with the employees paying a 4.5% share

[2]The remainder consists of private expenditures, as voluntary health insurance has a minimal role in the system.

[3]These include: children, students, women or men on parental leave, pensioners, unemployed individuals, people living below the poverty line, prisoners and asylum seekers.

and employers a 9.0% share, while the self-employed pay 13.5% of their contribution base, defined as 50% of their profits (Act no.592/1992 Coll.). There has been no annual ceiling on contributions since 2013, though there is a legally defined minimum contribution base for employees and employers, equal to the monthly minimum wage. For individuals without taxable income who do not qualify for any of the state insured groups, 13.5% of the monthly minimum wage applies. The minimum monthly contribution base for self-employed persons is 50% of the average monthly wage in Czechia from 2 years prior, multiplied by a conversion factor set by the government.

For economically inactive individuals (the "state insured") defined by law (group (ii)), the state makes contributions on their behalf based on an assessment base defined by law. In 2017, state contributed 920 CZK per person[4]. Notably, 70% of SHI revenues in the Czech Republic are raised through employer-employee contributions, but this comes from only about 40% of Czechs (Bryndová *et al.* 2023). Additionally, when a person becomes unemployed and falls in the group of state insured individuals (group (ii)), the contributions made on behalf of him/her are on average 2–5 times lower. This discrepancy makes the SHI revenues susceptible to workforce fluctuations and it proved to be a problem in the aftermath of 2008 financial crisis, when the losses in revenues had to be compensated by loans from government and slight increase in contributions for state insured individuals (Fall & Glocker 2018).

Private health expenditure has remained between 15% and 20% of total health expenditure over the past decade. Out-of-pocket payments primarily cover over-the-counter pharmaceuticals, co-payments for prescription drugs, above-standard medical procedures, and certain direct payments and surcharges for dental care (Bryndová *et al.* 2023).

The Czech Republic currently has seven health insurance funds acting as purchasers and payers of care, and individuals are free to choose their insurance (OECD and European Observatory on Health Systems and Policies 2021). Individuals may switch funds once every 12 months, either by January 1 or July 1. These funds collect SHI contributions from employers and employees, self-employed individuals, and those without taxable income who do not qualify for state-funded insurance. The GHIF manages the redistribution of collected contributions and state budget transfers among the health insurance funds. Since 2018, the redistribution formula has been based on age-gender risk adjustments

[4]As of January 1st 2025, the state contributed 2 127 CZK per person. The state contributions have markedly increased due to inflation and COVID-19 pandemic

and pharmacy-based cost group indices (Bryndová *et al.* 2023).

3.3 Data and methods

3.3.1 Macroeconomic indicators

Economic recession is usually defined as a period of declining economic activity that lasts for more than two consecutive quarters (Claessens & Kosse 2009). National Bureau of Economic Research (NBER) defines economic recession as a significant decline in economic activity, which is visible in decline in real GDP, retail sales, employment, real income and production and lasts for more than a few months (NBER 2010). Most commonly used proxies of business cycle in literature are GDP, debt as percentage of GDP, gross national product (per capita), unemployment rate, industrial production, average real earnings and consumer prices, the deviation from the GDP trend, the industry capacity utilization and the industry confidence indicator (Messina *et al.* 2009; Carneiro *et al.* 2012; Gerdtham & Johannesson 2005; Oyesanya *et al.* 2015). Di Matteo & Di Matteo (1998) claim that general economic activity (as represented by GDP) remains the most consistent and widely used predictor of over-time developments in health care expenditures. We use eight different macroeconomic indicators (nominal GDP[5], unemployment, industrial production, recession index, business cycle index, GDP gap, consumer price index and consumer expenditure), with nominal GDP being chosen as the primary business cycle indicator. The other indicators will serve for comparison of the size of the effect. Table 3.1 summarizes the data sources used in the analysis. All the data have quarterly frequence in years 2000 to 2017.

3.3.2 Healthcare system's revenues

The data from the Ministry of Health, Czech Republic (2018) contain information about health insurance funds' revenues from four resources: employers and employees, self-employed individuals, individuals without taxable income and state on behalf of state insured individuals.

Figure 3.1 depicts the evolution of total revenues and its components from 1st quarter 2000 to 4th quarter 2017. Contributions paid by employers and employees comprise a major part of total inflows, as opposed to contributions

[5]All the health insurance funds' inflows are also in nominal terms.

Table 3.1: Data sources

Data	Source
Health insurance fund's revenues	Ministry of Health, Czech Republic (2018)
Macroeconomic indicators	
Nominal GDP	Eurostat (2000-2017b)
Unemployment	OECD (2000-2017b)
Industrial production	OECD (2000-2017a)
Recession index	Federal Reserve Bank of St. Louis (2000-2017)
Business cycle index[a]	Czech National Bank (2018)
GDP gap	Czech National Bank (2018)
CPI	Czech Statistical Office (2000-2017)
Consumer expenditure	Eurostat (2000-2017a)

[a]Business cycle index is computed from GDP gap.

from self-employed individuals or individuals without taxable income. Contributions on behalf of state insured people make up around 22% of total revenues on average, even though they cover more than half of the population.

Figure 3.1: Composition of insurance funds' inflows

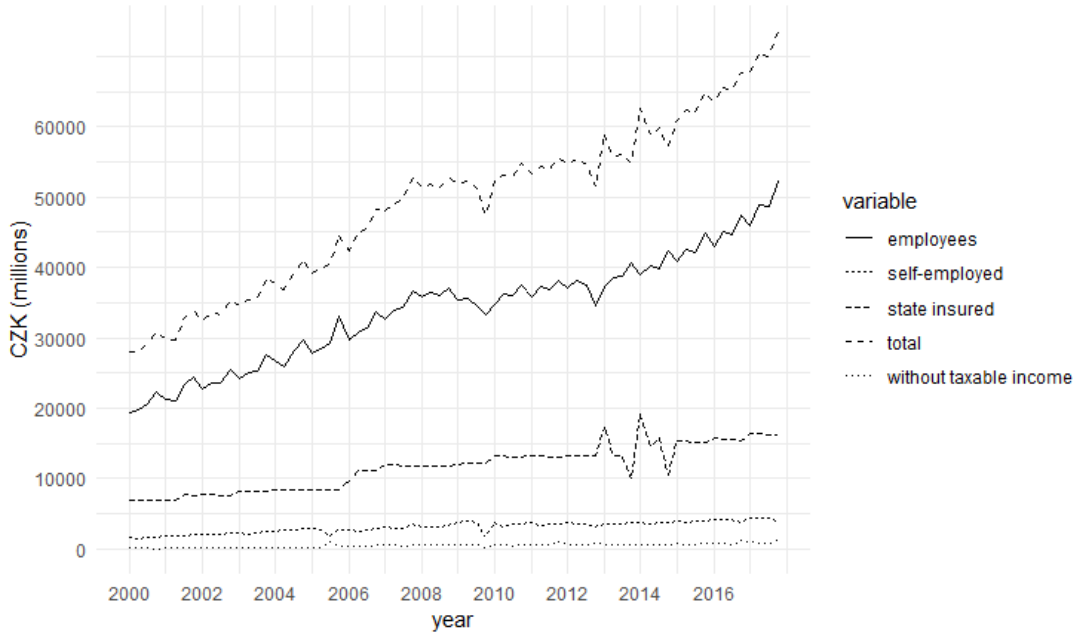


Figure 3.1 shows an increasing trend in all sources of revenues. In contributions from state, several changes occured that deserve a note. In 2006, the largest insurance fund in the Czech Republic (General Health Insurance Fund, GHIF) received an advanced payment (interest-free) from the state because it did not have enough resources to fulfil its liabilities in time, leading to delay in

payments to hospitals. This loan was repaid in 4 instalments in the second half of 2006 (Ministry of Finance, the Czech Republic 2007). The change in 2010 was caused by increase in the assessment base from which the contributions per person per month are computed. Significant changes occurred in years 2013 and 2014 where the state again provided advanced payment to the insurance funds due to their unfulfilled liabilities. This occurred in the first quarter of 2013 and 2014, with the size of advanced payment 4.8 and 4 billion, respectively (Czech Statistical Office 2014). Other than that, contributions from employees are growing quite steadily except for a short period of stagnation during the economic crisis in 2008. The other two sources of revenues (contributions from individuals without taxable income and from self-employed individuals) are rather negligible and are left out from the analysis.

3.3.3 Hypotheses

Several studies have already examined the relationship between the health care system's expenditures and the business cycle (Liang & Tussing 2019; Arze del Granado *et al.* 2013; Keegan *et al.* 2013; Portela & Thomas 2013). The relationship between the business cycle and healthcare system's revenues in the countries with the SHI scheme has not been tested yet, even though it is equally important as illustrated by the revenue shocks to SHI systems in Greece, Lithuania and Estonia (WHO 2017,WHO 2008,WHO 2015, Habicht *et al.* (2019)). We will test three hypotheses using standard econometric methodology for time series analysis:

1. (H1) Total health care system's revenues are pro-cyclical.
2. (H2) The employer-employee contributions are the most procyclical component.
3. (H3) The effects are lagged by one or multiple quarters.

First, based on the case studies from SHI systems (WHO 2017,WHO 2008, WHO 2015, Habicht *et al.* (2019)), we expect that during crises, the revenues of health insurance funds decrease due to stagnating wages, higher unemployment and decreased tax collections (H1). Second, the responsiveness of real wages to economic cycles (Verdugo 2016) indicates that labor market fluctuations directly impact wage-based contributions to healthcare funding. When economic conditions worsen, wage stagnation or declines among the workforce could reduce employer-employee contributions (H2). Third, based on New Keynesian

theory about wage stickiness and nominal rigidity, we expect that wages adjust with a delay, thus macroeconomic fluctuations do not immediately translate into wage-based contributions, but the effects span over several quarters (H3) (Barattieri *et al.* 2014). We also examine and compare the magnitudes of the effects.

3.3.4 Model specification

This study employs a regression framework to examine the impact of business cycle (represented by macroeconomic indicators) on healthcare system's revenues in the Czech Republic. The effect on three dependent variables is examined: overall healthcare system revenues, revenues from employer-employee contributions, and revenues from state on behalf of state insured individuals. The independent variables include the macroeconomic variable, seasonal dummies, and a lagged dependent variable to account for temporal autocorrelation and revenue persistence.

Endogeneity is a critical concern in this model, given the possible bidirectional relationship between healthcare system's revenues and macroeconomic conditions, and the inclusion of a lagged dependent variable. The following paragraphs outline potential sources of endogeneity and steps taken to address them.

Firstly, a possible bidirectional relationship may exist between healthcare system's revenues and macroeconomic variables, as while macroeconomic fluctuations are expected to influence healthcare revenues, substantial changes in healthcare funding could, in turn, impact economic performance. This endogeneity issue may lead to biased estimates, as healthcare revenues and macroeconomic variables could simultaneously affect each other within the same period. Although an instrumental variable approach could mitigate this issue, finding a valid instrument correlated with macroeconomic variables but unrelated to healthcare revenues is challenging in this context.

Secondly, the inclusion of a lagged dependent variable aims to capture the persistence in healthcare revenues over time and reduce serial correlation in the error term. However, adding a lagged variable can induce dynamic panel bias, especially in small sample contexts where the lagged dependent variable correlates with the error term, potentially skewing coefficient estimates. To evaluate the robustness of the lagged model, alternative lag structures were tested to verify consistency in the results.

Thirdly, omitted variables that influence both the macroeconomic variables and healthcare revenues could create spurious correlations, leading to biased estimates. For example, factors such as inflation rates or broader fiscal policy changes may simultaneously affect economic growth and public sector revenues, introducing omitted variable bias. Several variables (e.g. inflation, average wage) have been incorporated as independent variables when fitting the model and did not lead to significantly better fit, so they were ommited. Seasonal dummy variables for each quarter were included to control for predictable seasonal fluctuations in healthcare revenues, which reduces some sources of omitted variable bias.

In summary, while endogeneity poses challenges to causal interpretation, the inclusion of lagged dependent variables and seasonal dummies helps mitigate some potential biases. By considering endogeneity sources and conducting robustness checks, this study presents conditional associations that offer valuable insights into the relationship between the business cycle and healthcare system's revenues.

Static model

Firstly, to test H1 and H2, we estimate the following equation by ordinary least squares (OLS):

$$\begin{aligned}\Delta log(y_t) =& \beta_0 + \beta_1 \Delta log(y_{t-1}) + \beta_2 \Delta log(m_t) + \beta_3 q_1 + \\ & \beta_4 q_2 + \beta_5 q_3 + \epsilon_t, \quad t = 1, ..., T,\end{aligned} \tag{3.1}$$

where Δ indicates first-difference (all series are non-stationary in levels – see results of ADF test in Table 3.2). y_t represents health care system's revenues in year t (we perform the analysis separately for overall revenues, revenues from employers and employees and revenues from state on behalf of state insured individuals), β_0 is the constant term of the model, m_t is a macroeconomic variable representing the business cycle, q_1, q_2 and q_3 are dummy variables for the first, second and third quarter which account for seasonality and ϵ_t is the error term. We are interested in the magnitude and significance of β_2. $\beta_2 > 0$ implies pro-cyclical behaviour, $\beta_2 < 0$ indicates counter-cyclical behavior.[6] Value of $\beta_2 > 1$ indicates a more-than proportionate response of health care system's revenues to business cycle fluctuations.

[6]Vice-versa relationships hold for unemployment, recession index and GDP gap, since these business cycle indicators move in the opposite direction.

Table 3.2: ADF test

	Level		First Difference	
	Intercept	Intercept, trend	Intercept	Intercept, trend
$\log(total)$	1.42	−0.71	−8.52	−8.68
$\log(employees)$	2.43	1.04	−4.42	−4.39
$\log(si)$	−0.08	−3.46	−3.87	−3.97
$\log(nominal\ GDP)$	−0.06	−1.21	−3.63	−3.65

The critical value of the ADF statistic at the 5% level for T = 50 is approximately -2.93 (intercept only) and -3.50 (intercept and trend). Lags are chosen based on AIC.

Lagged regression

To examine whether the effects are lagged and test H3, we estimate the following model:

$$\begin{aligned}\Delta log(y_t) =&\beta_0 + \beta_1 \Delta log(y_{t-1}) + \sum_{k=1}^{4} \beta_k \Delta log(m_{t-k}) + \beta_3 q_1 + \\ &\beta_4 q_2 + \beta_5 q_3 + \epsilon_t, \quad t = 1, ..., T,\end{aligned} \tag{3.2}$$

where m_{t-k} is the k^{th} lag of the macroeconomic variable, so β_k represents the lagged effect. At first, 4 lags of macroeconomic variable are included because we have quarterly data and we suppose that the lagged effect will not persist for more than one year. To determine the optimal lag length, we first estimate models including one to four lags separately and compare their performance using the AIC and the BIC. These model comparison criteria help to balance goodness-of-fit against model complexity. Based on the AIC/BIC values, the specification with one lag of the macroeconomic variable was selected as the most parsimonious and robust model. Cross-correlation functions and specification tests such as the Cox test and the DavidsonÂ§-MacKinnon J-test were also considered, but ultimately the lag structure was finalized using the information criteria and economic reasoning about response dynamics.

All models satisfy the first three Gauss-Markov assumptions for time series data (*TS.1' Linearity and Weak Dependence, TS.2' No Perfect Collinearity, TS.3' Zero conditional mean*), which ensures that the estimators are consistent (Wooldridge 2012) (for more details, see Jeffrey Wooldridge, Introductory Econometrics: A Modern Approach). We also test for assumptions *TS.4' Ho-*

moskedasticity, and TS.5' No serial correlation using the Breusch-Pagan test and Breusch-Godfrey test. In case that heteroskedasticity and autocorrelation in error terms is present, we compute the Newey West standard errors, which are heteroskedasticity and autocorrelation robust (Andrews 1991; Wooldridge 2012).

3.4 Results

The results have shown that nominal GDP is the most sensitive business cycle indicator for health insurance funds' revenues. The models with nominal GDP are thus presented as a baseline model and models with the other business cycle indicators are shown for comparison.

3.4.1 Static model

Table 3.3 shows results of the static model which depicts the contemporaneous relationship between the business cycle and health care system's revenues. All variables are used in log-differences.

The results do not reject H1 and H2 and indicate pro-cyclical relationship in total health insurance funds' revenues and employer-employee contributions. In particular, the model estimates that if quarter-over-quarter GDP changes by 1%, then quarter-over-quarter total revenues will change by 0.7% in the same direction (i.e. total revenues are pro-cyclical). The effect on employer-employee contributions is larger and they respond more than proportionately to changes in nominal GDP: if quarter-over-quarter GDP changes by 1%, then quarter-over-quarter employer-employee contributions will change by 1.1%. State contributions on behalf of state insured individuals do not exhibit a significant relationship with nominal GDP.

The models' specification is checked using the residual analysis (see Figure C.1 for total revenues, Figure C.2 for employer-employee contributions and Figure C.3 for state contributions). The Breusch-Pagan test and Breusch-Godfrey test show heteroskedasticity and autocorrelation in error terms, so we compute heteroskedasticity and autocorrelation robust errors. Furthermore, outlying observations are found in state contributions which are due to advanced payments in 2013 and 2014. We include the original data in further models as we believe that the advanced payments reflect the economic situation.

Table 3.3: Static model

	Dependent variable y_t:		
	$\Delta\log(total)$	$\Delta\log(employees)$	$\Delta\log(si)$
Constant	0.025**	0.042***	−0.033
	(0.013)	(0.012)	(0.023)
$\Delta\log(y_{t-1})$	−0.518***	−0.407**	−0.568***
	(0.117)	(0.180)	(0.155)
$\Delta\log(nominal\ GDP_t)$	0.694**	1.112***	−0.631
	(0.339)	(0.318)	(0.837)
q_1	−0.013	−0.070***	0.127***
	(0.017)	(0.015)	(0.036)
q_2	−0.020	−0.042**	0.081**
	(0.014)	(0.018)	(0.034)
q_3	−0.018	−0.033***	0.033
	(0.014)	(0.012)	(0.029)
Observations	70	70	70
R^2	0.275	0.523	0.474

Note: Heteroskedasticity and autocorrelation robust Standard Error (SE) are reported in parentheses; si = state insured; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$;; y_{t-1} is the first lag of dependent variable.

3.4.2 Lagged regression

To test H3 and examine whether there is lagged effect of business cycle on health care system's revenues, we estimate a model with lagged values of GDP. The optimal lag selection is based on AIC and BIC tests, which are reported in Table C.1 in Appendix C. The AIC/BIC do not consistently favor the specific lags to be chosen for the model with total revenues as dependent variable (AIC prefers lag 2, BIC prefers lag 1), but the criteria are consistent to choose lag 2 of nominal GDP for employer-employee contributions and lag 1 for state contributions. For total revenues, we choose the second lag based on AIC[7]

The results of lagged regression are reported in Table 3.4. Total health insurance funds' revenues and employer-employee contributions have a significant pro-cyclical relationship with second lag of GDP. If quarter-over-quarter GDP lagged by two quarters changes by 1%, then total revenues change by 0.69%

[7]AIC is preferred over BIC in this context because it tends to favor models with better predictive accuracy.

and employer-employee contributions change by 0.72% in the same direction. In regression with state contributions, the coefficient on lagged GDP is insignificant. Thus, we do not reject H3 in total revenues and employer-employee contributions, and we reject H3 in state contributions.

A key finding across all three equations is the negative and significant coefficient on the lagged dependent variable, indicating mean reversion in quarterly growth rates of SHI revenues. This suggests that above-average growth in one quarter tends to be followed by below-average growth in the next, and vice versa. Such dynamics may be caused by administrative delays, payment timing, or cyclical corrections. From a policy perspective, this underlines the importance of not over-interpreting short-term fluctuations and ensuring that contribution systems have the capacity to absorb temporary volatility through stabilization mechanisms or reserves.

Table 3.4: Lagged model

	Dependent variable y_t:		
	$\Delta\log(total)$	$\Delta\log(employees)$	$\Delta\log(si)$
Constant	0.012^{**}	0.044^{***}	-0.055^{**}
	(0.006)	(0.015)	(0.026)
$\Delta\log(y_{t-1})$	-0.494^{***}	-0.297^{*}	-0.559^{***}
	(0.076)	(0.176)	(0.150)
$\Delta\log(nominal\ GDP_{t-1})$	–	–	1.304
			(0.803)
$\Delta\log(nominal\ GDP_{t-2})$	0.682^{*}	0.721^{*}	–
	(0.365)	(0.419)	
q_1	–	-0.072^{***}	0.129^{***}
		(0.016)	(0.036)
q_2	–	-0.034^{*}	0.080^{**}
		(0.017)	(0.034)
q_3	–	-0.035^{***}	0.032
		(0.013)	(0.029)
Observations	69	69	70
R^2	0.246	0.492	0.445

Note: Heteroskedasticity and autocorrelation robust SEs are reported in parentheses; si = state insured; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$;; y_{t-1} is the first lag of dependent variable.

The Breusch-Pagan test and Breusch-Godfrey test show heteroskedasticity and autocorrelation in error terms, so we compute heteroskedasticity and autocorrelation robust errors. The residual analysis of lagged models is summarized in Appendix C in Figure C.4, Figure C.5 and Figure C.6. As in the static model, residual plot of model with state contributions shows outlying observations which are due to advanced payments. Otherwise the models are well specified.

3.4.3 Other business cycle indicators

We examine the effect of other business cycle indicators on health care system's revenues, namely: unemployment, industrial production, recession index, BC index, GDP gap, consumer price index and consumer expenditure[8]. We compare the magnitude of the effects with the effect from the baseline model. The results in Table 3.5 support the hypothesis of pro-cyclicality in total healthcare system's revenues. The relationship between business cycle indicator and total revenues is only significant in case of unemployment and industrial production. If quarter-over-quarter unemployment changes by 1%, quarter-over-quarter total revenues will change by 0.14% in the opposite direction. If quarter-over-quarter industrial production changes by 1%, quarter-over-quarter total revenues will change by 0.22% in the same direction. Both of these effects are much smaller in magnitude compared to the baseline model.

Employer-employee contributions are pro-cyclical with different business cycle indicators (see Table 3.6). The effect is significant in case of unemployment, industrial production and also GDP gap, but in the last case, the coefficient is very close to zero. If quarter-over-quarter unemployment changes by 1%, the quarter-over-quarter contributions from employers and employees will change by 0.13% in the opposite direction. If quarter-over-quarter industrial production changes by 1%, the quarter-over-quarter employer-employee contributions will change by 0.33% in the same direction.

Lastly, Table 3.7 shows that there is no single significant relationship between the business cycle indicator and contributions from state and the signs do not suport the idea of counter-cyclicality.

[8]We intended to include average wage and interest rate as well, but these variables were not stationary even when log-differenced.

Table 3.5: Other business cycle indicators - contemporaneous relationship (total revenues)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	0.030**	0.030**	0.034**	0.023	0.032**	0.032**	0.026
	(0.013)	(0.013)	(0.014)	(0.015)	(0.013)	(0.013)	(0.016)
$\Delta\log(total_{t-1})$	−0.504***	−0.489***	−0.469***	−0.482***	−0.476***	−0.477***	−0.464***
	(0.117)	(0.119)	(0.096)	(0.104)	(0.112)	(0.118)	(0.120)
BC indicator[1]	**−0.136****	**0.223***	**−0.004**	**0.016**	**−0.000**	**0.563**	**0.229**
	(0.052)	(0.118)	(0.009)	(0.009)	(0.00000)	(0.797)	(0.345)
q_1	−0.011	−0.011	−0.013	−0.012	−0.012	−0.021	0.008
	(0.017)	(0.017)	(0.020)	(0.018)	(0.017)	(0.022)	(0.034)
q_2	−0.019	−0.019	−0.019	−0.019	−0.019	−0.022	−0.027
	(0.014)	(0.014)	(0.014)	(0.013)	(0.014)	(0.014)	(0.017)
q_3	−0.017	−0.017	−0.017	−0.015	−0.017	−0.019	−0.017
	(0.014)	(0.014)	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)
Observations	70	70	70	70	70	70	70
R^2	0.274	0.263	0.246	0.276	0.249	0.251	0.249

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3.6: Other business cycle indicators - contemporaneous relationship (employer-employee contributions)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	0.050***	0.049***	0.054***	0.046***	0.052***	0.053***	0.044***
	(0.013)	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.015)
$\Delta\log(employees_{t-1})$	−0.341**	−0.340**	−0.300**	−0.318**	−0.323***	−0.293*	−0.290*
	(0.164)	(0.166)	(0.115)	(0.132)	(0.088)	(0.167)	(0.172)
BC indicator[1]	**−0.134****	**0.331****	**−0.004**	**0.011**	**−0.000****	**1.286****	**0.326**
	(0.055)	(0.128)	(0.009)	(0.009)	(0.000)	(0.556)	(0.317)
q_1	−0.070***	−0.068***	−0.072***	−0.071***	−0.070***	−0.091***	−0.042
	(0.016)	(0.015)	(0.017)	(0.017)	(0.018)	(0.017)	(0.032)
q_2	−0.037**	−0.038**	−0.035**	−0.036**	−0.037**	−0.042**	−0.047**
	(0.017)	(0.017)	(0.015)	(0.015)	(0.015)	(0.018)	(0.020)
q_3	−0.033**	−0.033**	−0.033**	−0.031**	−0.033***	−0.037***	−0.034**
	(0.014)	(0.014)	(0.013)	(0.013)	(0.012)	(0.013)	(0.014)
Observations	70	70	70	70	70	70	70
R^2	0.482	0.492	0.460	0.472	0.472	0.485	0.466

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3.7: Other business cycle indicators - contemporaneous relationship (state contributions)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	-0.043^{*}	-0.037	-0.034	-0.054^{*}	-0.039	-0.040	-0.039
	(0.026)	(0.024)	(0.031)	(0.031)	(0.025)	(0.025)	(0.032)
$\Delta\log(si_{t-1})$	-0.585^{***}	-0.573^{***}	-0.575^{***}	-0.573^{***}	-0.573^{***}	-0.559^{***}	-0.574^{***}
	(0.157)	(0.158)	(0.147)	(0.073)	(0.106)	(0.145)	(0.160)
BC indicator[1]	**−0.204**	**−0.178**	**−0.011**	**0.027**	**0.000**	**−1.544**	**0.009**
	(0.133)	(0.320)	(0.023)	(0.023)	(0.000)	(1.839)	(0.738)
q_1	0.126^{***}	0.125^{***}	0.126^{***}	0.126^{**}	0.125^{***}	0.149^{***}	0.126^{*}
	(0.035)	(0.035)	(0.040)	(0.048)	(0.042)	(0.050)	(0.064)
q_2	0.083^{**}	0.081^{**}	0.082^{**}	0.082^{**}	0.081^{**}	0.088^{**}	0.081
	(0.035)	(0.034)	(0.036)	(0.037)	(0.037)	(0.037)	(0.049)
q_3	0.031	0.032	0.031	0.035^{*}	0.032	0.037	0.032
	(0.029)	(0.029)	(0.026)	(0.019)	(0.021)	(0.028)	(0.028)
Observations	70	70	70	70	70	70	70
R^2	0.479	0.473	0.473	0.482	0.473	0.477	0.471

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

The lagged regression with other business cycle indicators is shown in Table 3.8 for total revenues, Table 3.9 for employer-employee contributions and Table 3.10 for state contributions. Lag selection is based on AIC test which is provided in Appendix C for each business cycle indicator. For total revenues and employer-employee contributions, the results support the hypothesis of pro-cyclicality. The lagged effect of unemployment is no longer significant, whereas the effect of industrial production remains significant and is even larger compared to contemporaneous relationship in case of total revenues. Concerning the state contributions, we do not find any significant lagged relationship with business cycle and the signs of the effects do not clearly suggest either pro-cyclicality, or counter-cyclicality of state contributions.

Table 3.8: Other business cycle indicators - lagged relationship (total revenues)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	0.028**	0.027**	0.040***	0.030**	0.032***	0.029**	0.0001
	(0.013)	(0.012)	(0.012)	(0.015)	(0.011)	(0.013)	(0.016)
$\Delta\log(total_{t-1})$	−0.488***	−0.519***	−0.489***	−0.476***	−0.502***	−0.474***	−0.506***
	(0.126)	(0.113)	(0.108)	(0.111)	(0.085)	(0.114)	(0.104)
BC indicator[1] (lagged)	**−0.116**	**0.485****	**−0.016**	**0.004**	**0.000****	**0.965**	**1.235*****
	(0.141)	(0.187)	(0.009)	(0.009)	(0.000)	(0.801)	(0.349)
q_1	−0.010	−0.014	−0.014	−0.013	−0.012	−0.009	−0.008
	(0.017)	(0.016)	(0.018)	(0.017)	(0.020)	(0.017)	(0.016)
q_2	−0.017	−0.021	−0.019	−0.019	−0.020	−0.030**	0.098**
	(0.014)	(0.013)	(0.013)	(0.014)	(0.013)	(0.014)	(0.039)
q_3	−0.016	−0.019	−0.018	−0.017	−0.018*	−0.018	−0.059***
	(0.014)	(0.013)	(0.013)	(0.014)	(0.011)	(0.013)	(0.013)
Observations	68	68	70	70	68	70	70
R^2	0.270	0.339	0.276	0.247	0.316	0.262	0.380

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3.9: Other business cycle indicators - lagged relationship (employer-employee contributions)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	0.050***	0.049***	0.057***	0.052***	0.051***	0.050***	0.026*
	(0.013)	(0.013)	(0.012)	(0.015)	(0.012)	(0.013)	(0.016)
$\Delta\log(employees_{t-1})$	−0.328*	−0.342**	−0.307**	−0.302*	−0.320**	−0.330*	−0.348**
	(0.173)	(0.168)	(0.121)	(0.168)	(0.141)	(0.166)	(0.159)
BC indicator[1] (lagged)	**−0.126**	**0.218***	**−0.012**	**0.001**	**0.000****	**0.814**	**1.025*****
	(0.095)	(0.129)	(0.009)	(0.008)	(0.000)	(0.669)	(0.317)
q_1	−0.071***	−0.072***	−0.071***	−0.072***	−0.071***	−0.068***	−0.067***
	(0.016)	(0.015)	(0.017)	(0.015)	(0.017)	(0.016)	(0.014)
q_2	−0.036**	−0.038**	−0.035**	−0.035**	−0.035**	−0.046**	0.060
	(0.017)	(0.017)	(0.015)	(0.017)	(0.015)	(0.018)	(0.037)
q_3	−0.034**	−0.034**	−0.031**	−0.033**	−0.032**	−0.034**	−0.067***
	(0.014)	(0.013)	(0.013)	(0.014)	(0.014)	(0.013)	(0.011)
Observations	69	68	70	70	69	70	70
R^2	0.481	0.477	0.475	0.458	0.492	0.468	0.536

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 3.10: Other business cycle indicators - lagged relationship (state contributions)

	Business cycle indicator						
	unem	*ind. prod.*	*recession index*	*BC index*	*GDP gap*	*CPI*	*cons. exp.*
Constant	−0.036	−0.046*	−0.033	−0.045	−0.040	−0.041	−0.071**
	(0.025)	(0.026)	(0.030)	(0.030)	(0.026)	(0.027)	(0.032)
$\Delta\log(si_{t-1})$	−0.572***	−0.573***	−0.576***	−0.580***	−0.568***	−0.571***	−0.577***
	(0.159)	(0.153)	(0.154)	(0.097)	(0.148)	(0.157)	(0.158)
BC indicator[1] (lagged)	**0.120**	**0.439**	**−0.016**	**0.013**	**0.000**	**0.513**	**1.210***
	(0.109)	(0.360)	(0.022)	(0.022)	(0.000)	(1.462)	(0.614)
q_1	0.125***	0.126***	0.127***	0.124***	0.127***	0.125***	0.129***
	(0.035)	(0.036)	(0.036)	(0.044)	(0.037)	(0.038)	(0.036)
q_2	0.080**	0.083**	0.083**	0.081**	0.084**	0.080**	0.196**
	(0.034)	(0.035)	(0.035)	(0.036)	(0.035)	(0.037)	(0.075)
q_3	0.031	0.036	0.033	0.030	0.031	0.032	−0.010
	(0.029)	(0.029)	(0.028)	(0.019)	(0.029)	(0.031)	(0.033)
Observations	70	69	70	70	70	67	70
R^2	0.474	0.480	0.475	0.474	0.481	0.478	0.487

Note: [1]Business cycle indicator (as indicated in the table header) in log difference (except for recession index and BC index)
Heteroskedasticity and autocorrelation robust SE are reported in parentheses; * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

3.4.4 Summary of results

The results indicate that there is a significant pro-cyclical relationship between the business cycle (proxied by nominal GDP) and total health insurance funds' revenues in the Czech Republic. This effect is driven mainly by contributions from employers and employees that make a major part of total revenues. The pro-cyclicality in employer-employee contributions persists for two quarters, with the lagged effect being smaller. Contributions from state on behalf of economically inactive people do not display a significant relationship with business cycle in the Czech Republic.

The results of the baseline model are compared with the effect of seven different business cycle indicators. The magnitude of the effect with these indicators is smaller than the effect of nominal GDP and varies for different business cycle indicators. This is caused by the fact that the linkages between individual indicators and health insurance funds' revenues vary.

The results support our expectation that during economic downturns, employer-employee contributions decline. This occurs primarily because (i) wages tend to fall during recessions and (ii) individuals lose jobs and shift into the category of state-insured, where contributions are paid on their behalf by the government. The pro-cyclical effect is significant in both the contemporaneous and lagged models for total revenues and employer-employee contributions. The effect persists over two quarters, likely due to institutional and contractual frictions, such as wage stickiness and delayed layoffs, that prevent immediate adjustment in labor markets.

Given these dynamics, the preferred model specification is the dynamic model with one lag, which is slightly favored by AIC and BIC criteria for total revenues and state contributions. Although the static model performs marginally better for employer-employee contributions, the dynamic model is retained as the main specification. This choice is supported by the economic context, where administrative and behavioral delays in the social health insurance system imply that macroeconomic shocks may not translate into contribution flows immediately. The dynamic model thus better captures the real-world timing of the relationship between the business cycle and health insurance revenues.

3.4.5 Counterfactual scenario: a typical recession

To illustrate the practical policy implications of the model, we simulate the impact of a typical recession scenario on the revenues of the SHI system. Suppose that the economy experiences a moderate contraction of 3% in GDP over two consecutive quarters, and we wish to estimate the resulting revenue shortfall.

Given that the model is specified in log-differences, a 3% quarter-over-quarter drop in GDP corresponds to:

$$\Delta \log(GDP_{t-2}) = \log(0.97) \approx -0.0305$$

In the lagged model, the coefficient on $\Delta \log(GDP_{t-2})$ is estimated to be $\hat{\beta}_{GDP,t-2} = 0.682$ for total SHI revenues and $\hat{\beta}_{GDP,t-2} = 0.721$ for employer-employee contributions. Hence, the estimated decline in revenues two quarters after the GDP shock is:

$$\Delta \log(\text{Total Revenues}_t) = 0.682 \cdot (-0.0305) \approx -0.0208 \Rightarrow -2.08$$

$$\Delta \log(\text{Employee Contributions}_t) = 0.721 \cdot (-0.0305) \approx -0.0220 \Rightarrow -2.20\%$$

Additionally, the model includes a statistically significant negative coefficient on the first lag of the dependent variable. This implies that the initial decline is followed by a partial rebound, reflecting a tendency toward mean reversion. For instance, revenues might decline sharply two quarters after the shock but recover modestly thereafter, unless new adverse shocks occur.

These results demonstrate that even a moderate recession can lead to a drop of over 2% in SHI revenues, primarily driven by reduced wage-based contributions. Given the delay in the effect, policymakers need to monitor macroeconomic indicators proactively. Furthermore, this underscores the importance of maintaining adequate fiscal buffers or introducing automatic stabilizers in the SHI system to cope with cyclical revenue fluctuations.

3.5 Discussion

The results provide empirical evidence that current financing of the health care system in the Czech Republic is pro-cyclical. This finding implies a possible problem during economic downturns, when employer-employee contributions decline, so there are fewer resources available in insurance funds to pay for

health care provision. In case of severe crisis, this may pose a threat to health care providers and may lead to delayed care, which will have harmful consequences on the population in the long-term. The decrease in revenues occurs for two reasons: (i) employers release their employees during crisis, so individuals that used to contribute from their wages become eligible for state contributions, which are much lower and (ii) wages during crisis are stagnating, i.e. not growing. The analysis is based on data from the Czech Republic, one of the countries that rely on the SHI scheme. Our results are not directly applicable in other countries with SHI scheme as the resilience of the health care system's revenues depends on the relative importance of its sources.

Eight different business cycle indicators are used in the analysis. According to our results, the insurance funds' revenues are the most sensitive to nominal GDP, where the effect is the largest. This suggests that counter-cyclical policy could be determined based on the evolution of GDP. The next two indicators that are also statistically significant are the industrial production and unemployment.

The experience from the 2008 financial crisis has shown several possible mechanisms that European countries employed to effectively respond to the crisis and build resilience: counter-cyclical fiscal policies; adequate levels of public spending on health; no major gaps in health coverage; relatively low levels of out-of-pocket payments; etc. (WHO 2015). Some of these had already been in place in the Czech Republic prior to the crisis (e.g. low out-of-pocket payments, universal health coverage), but some could have been embraced in the aftermath of the financial crisis, such as counter-cyclical fiscal policies.

Focusing purely on countries relying on the SHI scheme, the decrease in healthcare system's revenues after the global financial crisis has been handled differently. In Estonia, the financial crisis led to decrease in SHI contributions by 11% in 2009 and by 5% in 2010 due to rising unemployment (WHO 2015). Estonia was well-prepared for the crisis thanks to large reserves that had been accumulated by the Estonian Health Insurance Fund (EHIF). Despite that, the reserves were not used to their full potential and budgetary cuts in healthcare were unavoidable (Habicht *et al.* 2019). As a consequence of the crisis, the Estonian government introduced a government transfer on behalf of pensioners as a part of the 2017 health reform to expand the revenue base. Before the reform, nearly half of the population was eligible for the health insurance with no contributions made on behalf of them (OECD 2019a; Habicht *et al.* 2019).

In Lithuania, unemployment more than tripled in one year, but health care

system's revenues were partially protected thanks to counter-cyclical mechanisms. The state contributions are defined as a share of average gross monthly salary, lagged by two years, and this share has been increasing over time. Thus, while the contributions from economically active population declined by 20% in 2009, this loss of revenue was covered by increasing state contributions, which more than doubled between 2007 and 2010. As a result, financing for health care was affected much less than the rest of economy (WHO 2015).

The economic crisis in Greece led to a rapid increase in unemployment, which resulted in significant decrease of social insurance revenues by 20.5% between 2008 and 2013. After receiving the financial aid from the Troika, Greece had to implement extensive austerity measures aiming at reducing public expenditures. From 2009 to 2013, Greece experienced an average drop in health expenditures per capita by 8.7% annually, one of the biggest reductions in OECD (WHO 2015). Around 2.5 million people lost their health insurance coverage after 2009 due to unemployment and it took until 2016 to ensure access to healthcare for the vulnerable groups (WHO 2017). The crisis highlighted the need for restructuring the health care system (WHO 2017). These examples demonstrate that relying mainly on employer-employee contributions does not provide a stable source of financing unless counter-cyclical mechanism are implemented.

During the 2008 financial crisis, the Czech Republic, like many other countries, implemented fiscal policy measures to mitigate the impacts of the economic downturn. Automatic stabilizers included for instance progressive taxes, unemployment benefits and social programs. Discretionary policy included increased government spending on infrastructure projects, subsidies for industries affected by the crisis, and tax cuts to stimulate consumer spending and business investment (Dolls *et al.* 2012). Between 2001 and 2011, the fiscal discretion operated mostly pro-cyclically and in minor cases also counter-cyclically (Ambrisko *et al.* 2012). Similarly as many EU countries, Czech Republic did not accumulate sufficient budgetary reserves prior to the financial crisis. This limited the use of counter-cyclical automatic stabilizers and the discretionary policy had to respond to high government deficits by consolidation in a pro-cyclical manner (Ambrisko *et al.* 2012).

The results of our analysis for total health insurance funds' revenues and employer-employee contributions are in accordance with other state activities: similarly as taxes, they also decrease during economic downturns and behave pro-cyclically. The state contributions do not display either pro-cyclical, or

counter-cyclical pattern, even though we would expect them to copy the trend of unemployment or social benefits which are counter-cyclical stabilizers. Contributions from state should be increased to offset the loss of revenue from economically active individuals during economic downturn. Additionally, in such a pro-cyclical system, the revenues are expected to diminish also in the context of ageing population, as the number of economically active people will decrease while the number of state insured individuals will increase

We contribute to current literature by examining the relationship between the business cycle and health insurance funds' revenues, which has not been done before. We quantify the effect of nominal GDP on total revenues, revenues from employers and employees and state contributions. We find that while employer-employee contributions are pro-cyclical, the revenues from state do not display any significant relationship with business cycle, so there is no evidence of counter-cyclicality which could help to stabilize the health care systems' revenues during economic crisis.

3.6 Conclusion

The resilience of healthcare system's revenues to business cycle fluctuations has been discussed especially after the onset of 2008 financial crisis, but the exact effect has not been measured. In this chapter, we focus on one of the two principal financing schemes in Europe – the SHI, which is financed mainly by economically active population. This makes the system vulnerable to business cycle fluctuations, unless counter-cyclical measures are implemented. In particular, we provide empirical evidence based on data from the Czech Republic, a country with the SHI scheme.

We estimate the effect of business cycle (proxied by eight different indicators) on health care system's revenues, and its two main components: employer-employee contributions and state contributions. We analyse the contemporaneous and lagged effect of business cycle. The most sensitive business cycle indicator is nominal GDP. The main results are based on the dynamic specification with one lag, which is slightly favored by model selection criteria for most revenue components and better reflects the real-world timing of how macroeconomic conditions translate into contribution flows within the social health insurance system. Total health care system's revenues are pro-cyclical, which is mainly driven by employer-employee contributions. Our model estimates that if quarter-over-quarter GDP increases by 1%, then quarter-over-quarter

lagged total revenues will increase by 0.7% and quarter-over-quarter lagged contributions from employees will increase by 0.7%. State contributions do not exhibit any significant relationship with business cycle proxied by nominal GDP. We also estimate the effect of different business cycle indicators (unemployment, industrial production, recession index, business cycle index, GDP gap, consumer price index and consumer expenditure), where pro-cyclicality is also found for total revenues and employer-employee contributions, but the magnitude of the effect is smaller than for nominal GDP.

We find evidence that the Czech health care system as an example country with the SHI scheme faces the challenge of vulnerability to economic shocks. Our results are in accordance with evidence from other countries with the SHI scheme (Greece, Estonia, Lithuania), where health care system's revenues significantly declined during the 2008 financial crisis (Simou & Koutsogeorgou (2014), Habicht *et al.* (2019), WHO 2013). We contribute to current literature by being the first to focus purely on health insurance funds' revenues and to estimate the magnitude of the effect of business cycle. Our results imply the need to increase the magnitude of state contributions in periods of economic downturns to compensate for the loss of revenue from economically active individuals in countries relying on the SHI scheme. The magnitude of the effect of economic downturn always depends on the relative importance of health care system's revenues.

Conclusion

This dissertation thesis is a collection of three health economics essays, which are based on three articles that have been recently published in respectable health economics journals. It focuses on three challenges in the Czech healthcare system: the substantial economic costs of obesity and smoking, and the revenue vulnerabilities of the statutory health insurance system. Together, these essays emphasize the interconnectedness of health behaviors and policy challenges, contributing valuable insights to the field of health economics.

The first two essays quantify the economic burden of obesity and smoking, two risk factors that are associated with higher risk of developing noncommunicable diseases such as cardiovascular diseases or some forms of cancer, which brings large socioeconomic costs. Employing the cost-of-illness (COI) framework, these studies provide comprehensive evaluations of both direct costs, such as healthcare expenditures, and indirect costs, including productivity losses due to absenteeism, presenteeism, and premature mortality. The findings highlight the substantial economic burden posed by these preventable conditions, emphasizing the need for targeted preventive interventions to reduce prevalence and associated costs. By adopting robust methodologies and incorporating sensitivity analyses, these essays also demonstrate the importance of methodological rigor in estimating economic impacts and informing policy decisions. These essays fill a significant gap in the literature by providing the first comprehensive quantification of these public health issues in the Czech Republic.

It is important to emphasize that the COI framework used in this thesis reflects only part of the total burden. Specifically, the analysis captures the first two components of the Health Production Function: direct healthcare costs and indirect productivity losses. It excludes the disutility from illness, such as pain, suffering, psychological distress, and quality-of-life losses, which are central to welfare economics but typically omitted from COI studies due to methodological and data constraints.

Accordingly, the reported results should be interpreted as conservative, lower-bound estimates. To provide a fuller picture, Appendix D complements the core analysis with illustrative estimates of intangible costs using welfare-economic approaches such as the VSL, the VSLY, and QALY- or DALY-based valuations. These additional figures underscore that the full societal burden of smoking and obesity likely exceeds the costs presented in the main chapters.

The findings from the first two chapters contribute to policymaking in the Czech Republic by providing robust, localized evidence on the economic burden of obesity and smoking. The analysis offers a data-driven foundation for evaluating public health interventions such as taxation, behavioral prevention programs, and resource allocation. Importantly, the estimates are broken down by cost category (e.g., absenteeism, presenteeism, premature mortality), helping to identify high-impact areas for targeted policy response.

These results also update and expand the existing evidence base for the Czech Republic, using transparent and reproducible methods that enhance comparability with international studies. While global literature confirms the high economic costs of obesity and smoking, localized cost estimates are essential for adapting policy to national institutions, labor market conditions, and healthcare system design. As such, the findings can inform priority-setting, budget planning, and economic evaluations of preventive health policies.

The third essay shifts focus to the inflows of the Czech healthcare system, specifically examining how statutory health insurance revenues are influenced by economic fluctuations. The analysis reveals the vulnerabilities of a wage-based contribution system to business cycle dynamics, showing procyclicality in overall healthcare system's revenues. This essay's findings highlight the need for countercyclical mechanisms to stabilize healthcare financing and ensure the continuity of services during recessions.

Collectively, these essays highlight the dual pressures faced by the Czech healthcare system: the growing financial burden of non-communicable diseases and the instability of revenue streams tied to macroeconomic conditions. Addressing these challenges requires an integrated approach that combines effective prevention strategies with resilient financing mechanisms. By demonstrating these issues, this dissertation provides valuable insights for policymakers to enhance health outcomes and economic sustainability.

Looking forward, future research could expand on these findings by incorporating cross-national comparisons to understand how other countries tackle similar challenges. Additionally, exploring the integration of innovative funding

models or prevention strategies, such as digital health interventions or disease management programs, could further enrich the discussion and inform more sustainable healthcare policies. These extensions would build on the foundation laid by this dissertation, advancing practical solutions in health economics.

Looking forward, future research could build on this dissertation by integrating both cost- and welfare-based approaches, enabling a more comprehensive evaluation of health risks and policy options. Incorporating welfare-based metrics would be particularly valuable for assessing trade-offs in public health decision-making, especially when comparing interventions that affect mortality, morbidity, and quality of life in different ways. In addition, cross-national comparisons could shed light on how other countries address similar challenges, while exploring innovative funding models or prevention strategies, such as digital health tools or disease management programs, could inform the development of more sustainable and effective healthcare policies. These extensions would advance the practical relevance of health economics and contribute to evidence-based policymaking.

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Appendix A

Appendix to Chapter 1: Economic Burden of Obesity in the Czech Republic

A.1 Literature Review

Table A.1: Literature review - direct costs

	n	country	method	number of comorbidities	population	normal weight	overweight	obesity	% of healthcare costs
Arterburn *et al.* (2005)	16 262	USA	econometric approach	N/A	18+	$2 424	$2 664	$2 984-4 399[a]	N/A
Finkelstein *et al.* (2005)	20 329	USA	econometric approach	N/A	18-64 women 18-64 men	0 (base)	$495 $169	$1 071-1 549[a] $392-1 591[a]	N/A
Cawley & Meyerhoefer (2012)	23 689	USA	econometric approach	NA	11-64	$1 763		$4 458	20.6%
Kleinman *et al.* (2014)[b]	72 778	USA	econometric approach	N/A	18+ women 18+ men	$4 142 $2 861	$4 583 $3 378	$6 328 $4 309	N/A
An (2015)	125 955	USA	econometric approach	N/A	18+ women 18+ men	0 (base)	N/A	$1 525 $1 160	N/A
Borg *et al.* (2005)	23 365	Sweden	econometric approach (total costs)	N/A	30-60 women 30-60 men	0 (base)	$101 million[c] $169 million		2.3%
Sander & Bergemann (2003)	N/A	Germany	top-down approach	4	25+	N/A	N/A	€2 billion	N/A
Konnopka *et al.* (2011)	N/A	Germany	top-down approach	16 (W), 17 (M)	18+	N/A	€4 854 million		2.1%
Lehnert *et al.* (2015)	N/A	Germany	top-down approach	16 (W), 17 (M)	18+	N/A	€8 647 million		3.27%
Schmid *et al.* (2005)	N/A	Switzerland	top-down approach	18	15+	N/A	CHF 1 077-1 615 million		2.3-3.5%
Kang *et al.* (2011)[d]	1.9 mil	Korea	top-down approach	7	20+	N/A	$270.5 million	$810.5 million	3.7%
Dee *et al.* (2015)	N/A N/A	Northern Ireland Republic of Ireland	top-down approach	16	N/A	N/A	€127 million €437 million		2.8% 2.7%
Krueger *et al.* (2015)	N/A	Canada	top-down aproach	16 13	12+ women 12+ men	N/A	$4.3 billion $4.8 billion	$7.6 billion $6.6 billion	6.7%
Hodycová (2009)	N/A	Czech Republic	top-down approach	7[e]	18+	N/A	N/A	9.5 billion CZK[f]	5.2%
Tuzarová (2016)	N/A	Czech Republic	top-down approach	18 (W), 16 (M)	18+	N/A	N/A	7.6 billion CZK	3.45%
Effertz *et al.* (2016)	146 000	Germany	bottom-up approach	NA	15+	N/A	N/A	€29.39 billion	7.9%[g]

[a] *Range for obesity class I-III.* [b] *Normal weight is classified as BMI < 27, overweight: $27 \leq BMI < 30$, obesity: $BMI \geq 30$.* [c] *Values are converted from SEK by a rate US$1 = SEK8.* [d] *In Korea, classification of obesity according to BMI is different than in Europe (Overweight: 23-24.9 kg/m^2; Obesity I: 25-29.9 kg/m^2; Obesity II: $\geq$ 30 kg/m^2).*
[e] *Cardiovascular diseases are taken as one comorbidity.* [f] *6.7 billion healthcare utilization, 2.6 billion pharmacotherapy.* [g] *Percentage of healthcare costs stated in OECD (2019b).*

Table A.2: Literature review - absenteeism

	n	country	measurement unit	population	normal weight	overweight	obesity
Konnopka *et al.* (2011)	N/A	Germany	number of days/year	15+	0 (base)	5 875 022 days	
			total yearly costs			€646 million[a]	
Lehnert *et al.* (2014)	7 990	Germany	yearly costs per person (days absent/year)	18-65 women	0 (base)	€284 (3.64 days)	€405 (5.19 days)
			yearly costs per person (days absent/year)	18-65 men		N/A (N/A)	€367 (3.48 days)
			total yearly costs	18-65		€2.18 billion[b]	
Lehnert *et al.* (2015)	N/A	Germany	number of days/year	15+	0 (base)	11 478 208 days	
			total yearly costs			€1.28 billion[c]	
Effertz *et al.* (2016)	146 000	Germany	total yearly costs	15+	0 (base)	N/A	€3.87 billion
Finkelstein *et al.* (2005)	25 427	USA	yearly costs per person (days absent/year)	18-64 women	$0 (base)/(3.4 days)	$93 (3.9 days)	$302-805 (5.2-8.2 days)[d]
			yearly costs per person (days absent/year)	18-64 men	$0 (base)/(3 days)	$6 (3 days)	$70-436 (3.5-5 days)
Finkelstein *et al.* (2010)	24 140	USA	yearly costs per person (days absent/year)	18+ women	0 (base)	$147 (1.1 days)	$407-1262 (3.1-9.4 days)[d]
			yearly costs per person (days absent/year)	18+ men		$85 (0.5 days)	$277-1026 (1.6-5.9 days)
Dall *et al.* (2009)	225 mil	USA	yearly costs per person	18+	0 (base)	$47	$104-264[d]
			total yearly costs			$3.5 billion	$3.9-6.8 billion
Andreyeva *et al.* (2014)	14 975	USA	yearly cost per person (days absent/year)	18+	0 (base)/(4.25 days)	N/A (4.48 days)	$216-348 (5.42-6.13 days)[d]
			total yearly costs		0 (base)	N/A	$8.65 billion
Kleinman *et al.* (2014)[5]	72 778	USA	yearly costs per person (days absent/year)	18+ women	$890 (4.09 days)	$1046 (5.02 days)	$1 175 (5.81 days)
			yearly costs per person (days absent/year)	18+ men	$615 (2.66 days)	$640 (2.81 days)	$792 (3.7 days)
Kang *et al.* (2011)	1.9 mil	Korea	total yearly costs	20+ women	0 (base)	$29.5 million	
				20+ men		$44.4 million	
Dee *et al.* (2015)	N/A	Northern Ireland	total yearly costs	N/A	0 (base)	€215 million	
		Republic of Ireland	total yearly costs			€136 million	
Neovius *et al.* (2012)	45 920	Sweden	**lifetime** productivity losses	19-65 men	€12 500	€15 000	€16 100
Tuzarová (2016)	N/A	Czech Republic	number of days/year	24-60 women &	0 (base)	N/A	3.7 million days
			total yearly costs	25-64 men			3.2 billion CZK

[a] *€481 million without unpaid work.* [b] *€1.37 billion women and €0.81 billion men.* [c] *€858 million without unpaid work.* [d] *Range for obesity class I-III.*
[e] *Normal weight: BMI* < 27*; overweight: BMI* > 27 *and* < 30.

Table A.3: Literature review - presenteeism

	n	country	measurement unit	gender	normal weight	overweight	obesity		
							class I	class II	class III
Boles *et al.* (2004)[a]	2 264	USA	productivity loss (%)	both	5.6	7.1			
			productivity loss (days)		14.0	17.6			
Pelletier *et al.* (2004)[a]	500	USA	productivity loss (%)	both	4.7	7.9			
			productivity loss (days)		11.8	19.8			
Burton *et al.* (2005)	28 375	USA	productivity loss (%)	both	0 (base)	N/A	1.5		
			productivity loss (days)			N/A	3.8		
Ricci & Chee (2005)	7 000	USA	weekly hours lost	both	4.2	4.2	4.8		
			productivity loss (days)		26.3	26.3	30		
Gates *et al.* (2008)[b]	341	USA (KY)	productivity loss (%)	both	3.3	3.1	2.5	4.2	
			productivity loss (days)		8.1	7.8	6.1	10.4	
Finkelstein *et al.* (2010)	10 262	USA	productivity loss (days)	women	0 (base)	0.9	6.3	11.0	22.7
	13 878			men		-3.3	2.3	5.8	21.9
Goetzel *et al.* (2010)[c]	10 026	USA	productivity loss ($)	both	1200	1402	1416		
			productivity loss (days)		5.8	6.8	6.9		
Kirkham *et al.* (2015)	17 089	USA	productivity loss (days)	both	4.2	N/A	N/A	4.7	
Gupta *et al.* (2015)	31 653	FRA, DE, IT ESP, UK	productivity loss (%)	both	16	15.6	17.6	20.4	29.2
			productivity loss (days)		40	39.1	44.0	50.9	73.0

Productivity loss in days is annual; conversion from productivity loss in percent to productivity loss in days is done assuming 250 working days per year
[a] *Compares normal weight against BMI<18.5 or >24.9.*
[b] *Compares BMI categories with BMI<24.9 (normal weight + underweight).* [c] *The study uses average wage rate $25.67/hour.*

Table A.4: Literature review - premature mortality

	n	country	measurement unit	discount rate	population	normal weight	overweight	obesity
Konnopka *et al.* (2011)	N/A	Germany	annual number of deaths total productivity lost	5%	15+	0 (base)	36 653 €3 381 million	
Lehnert *et al.* (2014)	N/A	Germany	annual number of deaths total productivity lost	5%	15+	0 (base)	47 964 €5 669 million	
Effertz *et al.* (2016)	146 000	Germany	annual number of deaths amount of lost years total productivity lost	2%	15+	0 (base)	N/A	101 886 2 072 million €23.12 billion
Fontaine *et al.* (2003)	23 659	USA	years of life lost per person	N/A	15-75 women 15-75 men	N/A	<1 year <1 year	3-8 years[a] 3-13 years[a]
Dall *et al.* (2009)	225 million	USA	total productivity lost per capita productivity lost	3%	18+	0 (base)	$1.9 billion $25	$6.9-25.9 billion[b] $182-1006[b]
Borg *et al.* (2005)	23 365	Sweden	total productivity lost	3%	30-60 women 30-60 men	0 (base)	$1.15 million 3.3 million	$64.0 million 298.5 million
Neovius *et al.* (2012)	45 920	Sweden	per capita productivity losses	3%	18+ men	€25 100	€31 800	€52 100
Dee *et al.* (2015)	N/A	Northern Ireland Republic of Ireland	total productivity lost	4%	18-75 18-75	0 (base)	€147 million €593 million	
Kang *et al.* (2011)	1.9 million	Korea	total productivity lost	6%	20+ women 20+ men	0 (base)	$70 million $374 million	
Tuzarová (2016)	N/A	Czech Republic	amount of lost years total productivity lost amount of lost years ($) total productivity lost	1.5%	25-60 women 25-64 men	0 (base)	N/A	5 440 years 395 million CZK 2 290 years 800 million CZK

[a] *Range for different BMI groups, BMI = 24 is used as reference category.* [b] *Range for obesity class I-III.*

Appendix B

Appendix to Chapter 2: Economic Burden of Smoking in the Czech Republic

B.1 Literature Review

Table B.1: Literature review

study	country	year	age	method	costs included	number of diseases[a]	discount r. (growth r.)	direct costs	indirect costs	total costs	% of HE[b]	% of GDP
Goodchild *et al.* (2018)	global	2012	30-69	Direct costs estimated based on other studies (proportion of total health expenditures attributable to smoking was found in literature), indirect costs: HCA.	direct costs, indirect costs (productivity losses due to morbidity and mortality)	5 groups of diseases	3% (growth rate spec. for each country)	$422 bn	$1014 bn	$1436 bn	5.7%	1.8%
Jarvis *et al.* (2012)	EU27	2009	35+	Direct costs: SAF for disease groups based on Peto *et al.* (1992), productivity losses: SAF for disease groups based on Austria and Germany, prem. mort.: percentage of deaths based on Peto *et al.* (1992) and WTP approach.	direct costs, indirect costs (productivity, losses[c], cost of premature mortality)	6 groups of diseases	–	€25 bn	€524 bn[d]	€549 bn	2.9%	4.40%
Wacker *et al.* (2013)	Germany	2008	32-81	Direct costs: bottom-up approach based on self-reported healthcare utilization in past 3 months, indirect costs: HCA based on self-reported absent days due to sickness.	direct costs, indirect costs (absenteeism, disability benefits)	–	–	€17.9 bn	€13.4 bn	€31.3 bn	–	1.23%

Koronaiou & Delipalla (2019)	Greece	2017	30-69	Direct costs: SAF of health expenditures by financing source, indirect costs: HCA (SAF of mortality and morbidity due to 32 diseases). Includes SHS exposure.	direct costs, indirect costs (productivity losses due to morbidity and mortality)	32	0% (1%)	€2.94 bn	€3.6 bn	€7.2 bn[e]	20.29%	4%
Lasocka *et al.* (2013)	Poland	2004-10	35+	Indirect costs: HCA.	indirect costs: prem. mortality, absenteeism, presenteeism, costs of acquired work disability	15 (not specified) for prem. mortality, 3 groups for absenteeism	5% (1%)	–	15 bn PLN (€3.75 bn)	–	–	2.6%
Allender *et al.* (2009)	UK	2005	–	direct costs: SAF of National Health Service (NHS) costs for disease groups, indirect costs: proportion of deaths and DALYs attributable to smoking.	direct costs, indirect costs (prem. mortality and morbidity)	11 groups of diseases	–	£5.2 bn	6 277 817 (12.1%) DALYs, 109 164 (18.6%) deaths	–	5.5%	0.37%
Lievens *et al.* (2017)	Belgium	2012	0-70	Direct costs: SAF for diseases, indirect costs: HCA; DALYs for intangible costs (1 DALY = €40 000).	tangible: direct costs, indirect costs (disability, prem. mortality); intangible costs	not specified (from other studies[f])	–	€727 m	€746 m	€1473 m (T), 295 406 DALYs (€11.8 bn) (I)	–	0.4%

Bolin *et al.* (2011)	Sweden	2007	35-84	direct costs: SAF for diseases, indirect costs: HCA.	direct costs, indirect costs (prem. mortality, permanent disability)	22	5% (−)	$480 m	$1134 m	$1.6 bn	1.17%	0.4%
Xu *et al.* (2021)	US	2010-14	18+	Direct costs estimated using two-part regression model.	direct costs	−	−	$227 bn	−	−	11.7%	1.3%
Shrestha *et al.* (2022)	US	2018	18+	HCA (regression model).	indirect costs (absenteeism, presenteeism, household productivity, inability to work)	−	−	−	$184.9 bn[g]	−	−	0.9%
US Department of Health and Human Services (2014)	US	2005-09	35+	HCA (updated SAM-MEC methodology).	indirect costs (prem. mortality), including value of unpaid work	24	−	−	$150.7 bn	−	−	1.0%
Krueger *et al.* (2015)	Canada	2013	12+	Direct costs: SAF of healthcare costs by disease group, indirect costs: modified HCA (includes value of unpaid work).	direct costs, indirect costs (disability and prem. mortality)	6 groups of diseases	−	CAD6.4 bn	CAD12.3 bn	CAD18.7 bn	−	1.0%
John *et al.* (2021)	India	2017-18	35+	Direct costs: attributable risk approach, indirect costs: HCA. Cost estimates are for all diseases combined using all-cause mortality RRs from tobacco.	direct costs, indirect costs (morbidity and prem. mortality)	−	3% (7.3%)	$6.0 bn	$21.5 bn	$27.5 m	5.3%	1.0%

Cher *et al.* (2017)	Singapore	2014	0+	Direct costs: SAF of healthcare costs by disease group, indirect costs: HCA.	direct costs, indirect costs (absenteeism, presenteeism and prem. mortality)	4 for direct costs and absenteeism, 16 for prem. mort.	3% (2%)	$14.9 m	$464.9 m	$479.8 m	–	0.2%
Anh *et al.* (2016)	Vietnam	2011	18+	Direct costs: SAF of healthcare costs by disease group, indirect costs: HCA.	direct costs, indirect costs (absenteeism, prem. mortality, income losses of family members providing patient care)	5	3% (6%)	$592.4 m	$580.7 m	$1173.2 m	5.76%	1.0%
Yang *et al.* (2011)	China	2008	35+	Direct costs: SAF of healthcare costs by disease group, indirect costs: HCA.	direct costs, indirect costs (absenteeism, prem. mortality and others[h])	3 groups of diseases	3% (10%)	$6.2 bn	$22.7 bn	$28.9 bn	3%	0.7%
Sung *et al.* (2014)	Taiwan	2010	35+	Direct costs: SAF of healthcare costs by disease, indirect costs: HCA. Includes SHS exposure.	direct costs, indirect costs (morbidity, prem. mortality)	19	3% (4%)	$828 m	$842 m	$1670 m[i]	3.4%	0.4%
Whetton *et al.* (2019)	Australia	2015-16	0+	Direct costs: SAF of healthcare costs by disease, indirect costs: HCA. Includes SHS exposure, value of unpaid work and intangible costs.	tangible: direct costs, indirect costs[j]; intangible costs	49 for smoking, 9 for SHS exposure	7% (–)	$6.7 bn	$12.5 bn	$19.2 bn (T), $117.7 bn (I)	4.4%	1.6%

Boachie *et al.* (2021)	South Africa	2016	35-74	Direct costs: SAF of healthcare costs by disease, indirect costs: HCA.	direct costs, indirect costs (absenteeism and prem. mortality)	10 groups of diseases	3.45% (1%)	$1.0 bn	$1.9 bn	$2.9 bn	4.1%	0.97%

[a] *Complete list of included diseases (where applicable) is presented in Table B.2.*

[b] *HE = health expenditures.*

[c] *Includes workplace absenteeism, early retirement and other long-term incapacity.*

[d] *Productivity losses €7 bn, prem. mort. €517 bn.*

[e] *€6.6 bn due to smoking, €0.6 bn due to SHS exposure (8.9% of total costs);*

[f] *Rehm* et al. *(2006) and US Department of Health and Human Services (2014).*

[g] *Absenteeism $9.4 bn, presenteeism $46.8 bn, home productivity $12.8 bn, inability to work $116 bn.*

[h] *Other indirect costs: transportation, nutritious supplemental food, caregiver costs during the inpatient hospitalizations and outpatient visits due to treating smoking-related diseases.*

[i] *$1543 m due to smoking, $126 m due to SHS exposure (7.5% of total costs).*

[j] *Indirect costs include: spending on tobacco by dependent smokers, absenteeism, presenteeism, premature mortality, fires, litter, value of unpaid work.*

Table B.2: List of diseases included in studies from literature review

study	included diseases	ICD-9/ICD-10 codes
Goodchild *et al.* (2018)	Tuberculosis	
	Lower respiratory infections	
	Malignant neoplasms	
	Cardiovascular diseases and respiratory diseases	
Jarvis *et al.* (2012):	Lung cancers (includes trachea, bronchus and lung cancers)	
	Upper aerodigestive cancers (includes mouth, oropharynx and oesophagus cancer)	
	Other forms of cancer	
	Cardiovascular diseases (includes ischaemic heart disease and cerebrovascular disease; but excludes rheumatic, hypertensive, and inflammatory heart diseases, and other cardiovascular diseases)	
	Chronic obstructive pulmonary disease	
	Acute respiratory illnesses (includes: asthma, lower respiratory infections, but excludes: tuberculosis, upper respiratory infections and otitis media)	
Koronaiou & Delipalla (2019)	**Communicable diseases**	
	Respiratory infections and tuberculosis	
	Tuberculosis	
	Lower respiratory infections	
	Non-communicable diseases	
	Neoplasms	
	Esophageal cancer	
	Stomach cancer	
	Liver cancer	
	Larynx cancer	
	Tracheal, bronchus, and lung cancer	
	Breast cancer	
	Cervical cancer	
	Prostate cancer	
	Colon and rectum cancer	
	Lip and oral cavity cancer	
	Nasopharynx cancer	
	Other pharynx cancer	
	Pancreatic cancer	
	Kidney cancer	
	Bladder cancer	
	Leukemia	

	Cardiovascular diseases	
	Ischemic heart disease	
	Stroke	
	Atrial fibrillation and flutter	
	Aortic aneurysm	
	Peripheral artery disease	
	Chronic respiratory diseases	
	Chronic obstructive pulmonary disease	
	Asthma	
	Digestive diseases	
	Neurological disorders	
	Diabetes mellitus	
	Musculoskeletal disorders	
	Injuries	
	Transport injuries	
	Unintentional injuries	
	Self-harm and interpersonal violence	
Lasocka *et al.* (2013)	Cancer	
	Diseases of cardiovascular systems	
	Diseases of respiratory systems	
Allender *et al.* (2009):	**Conditions related to smoking**	
	Mouth and oral cancer	
	Trachea/bronchus/lung cancer	
	Other cancers	
	Chronic obstructive pulmonary disease	
	Cardiovascular diseases	
	Other medical conditions: includes peptic ulcer and all respiratory conditions except chronic obstructive pulmonary disease	
	Total related to smoking	
	Communicable diseases, maternal/perinatal conditions and nutritional deficiencies	
	Digestive diseases (excluding peptic ulcer)	
	Diabetes mellitus	
	Diseases of the genitourinary system	
	Neuropsychiatric disorders	
	Musculoskeletal diseases	
	Injuries and accidents	
	Other	
Bolin *et al.* (2011)	**Cancer**	
	Lip, oral cavity, pharynx	C00–C14
	Esophagus	C15
	Stomach	C16
	Pancreas	C25

	Larynx	C32
	Trachea, lung, bronchus	C33–C34
	Cervix uteri	C53
	Kidney and renal pelvis	C64–65
	Urinary bladder	C67
	Acute myeloid leukemia	C92.0
	Cardiovascular conditions	
	Ischaemic heart diseases	I20–I25
	Other heart diseases	I00–I09;I26–I51
	Cerebrovascular disease	I60–I69
	Atherosclerosis	I70
	Aortic aneurysm	I71
	Arterial disease	I72–I78
	Respiratory conditions	
	Pneumonia	J10–J18
	COPD	J40–J44; J47
	Perinatal conditions	
	Short gestation/low birthweight	P07
	Respiratory distress syndrom	P22
	Other respiratory, newborn	P23–P28
	Sudden infant death	R95
Krueger *et al.* (2015):	Cardiovascular diseases	
	Cancers	
	Musculoskeletal diseases	
	Respiratory diseases	
	Diabetes	
	Others	
Cher *et al.* (2017):	**medical costs and costs of absenteeism:**	
	Lung cancer	
	Ischaemic heart disease	
	Stroke	
	COPD	
	premature mortality:	
	Mouth cancer	
	Oesophagus cancer	
	Lung cancer	
	Larynx cancer	
	Pancreas cancer	
	Bladder cancer	
	Kidney cancer	
	Stomach cancer	
	Uterus cancer	
	Ischaemic heart disease	
	Stroke	
	COPD	
	Parkinson's disease	
	Lower respiratory tract infection	
	Low birth weight	

	Fire injuries	
Anh *et al.* (2016)	Lung cancer	
	Cancers of the upper aerodigestive tract	
	Chronic obstructive pulmonary disease	
	Ischaemic heart disease	
	Stroke	
Yang *et al.* (2011)	Cancer	C00–C97
	Cardiovascular diseases	I00–I99
	Respiratory diseases	J00–J99
Sung *et al.* (2014)	**Cancer**	
	Lip/oral cavity/pharynx	140–149
	Oesophagus	150
	Stomach	151
	Rectum	154
	Liver/gallbladder/bile ducts	155–156
	Lung*	162
	Cervix uteri	180
	Cardiovascular disease	
	Rheumatic HD	390–39)
	Ischaemic HD*	410–414
	Cardiac arrest and other HD	420–429
	Cerebrovascular disease*	430–438
	Respiratory disease	
	Chronic bronchitis	491
	Asthma*	493
	Chronic airway obstruction	496
	Digestive system disease	
	Peptic ulcer, GI haemorrhage	531–533
	Liver cirrhosis	571
	Other smoking-related disease	
	Diabetes mellitus	250
	Kidney diseases	580–589
	Accidents	800–949
	Other SHS-associated disease	
	COPD	490–492, 496
	Breast cancer	174
Whetton *et al.* (2019)	Tuberculosis	A15, A16, A19, B90
	Lip and oral cavity cancer	C00–C09, C14
	Nasopharynx cancer	C10–C13
	Oesophageal cancer	C15
	Stomach cancer	C16
	Colon and rectum cancer	C18–C20
	Liver cancer	C22
	Pancreatic cancer	C25
	Cancer of nasal cavity	C30
	Cancer of accessory sinuses	C31.8

	Larynx cancer	C32
	Tracheal, bronchus, and lung cancer	C33–C34
	Cervical cancer	C53
	Endometrial cancer (protective)	C54.1
	Kidney cancer	C64–C65
	Bladder cancer	C66–C67
	Acute myeloid Leukaemia	C92
	Diabetes mellitus type 2	E11
	Parkinson's disease (protective)	G20
	Cataract	H25–H26
	Macular degeneration	H35.3
	Hypertensive heart disease	I11
	Ischaemic heart disease	I20–I25
	Atrial fibrillation and flutter	I48
	Other cardiovascular and circulatory diseases	I46–I47, I49–I52, I77-I79
	Ischaemic stroke	I63, I64, I65, I66, I69.3, I69.4
	Haemorrhagic stroke	I60, I61, I62, I69.0, I69.1, I69.2
	Atherosclerosis	I70
	Aortic aneurysm	I71
	Peripheral vascular disease	I72–I74
	Influenza and pneumonia	J10–11, J12–J18
	Chronic obstructive pulmonary disease	J43–J44
	Asthma	J45–J46
	Interstitial lung disease and pulmonary sarcoidosis	J84
	Other chronic respiratory diseases	J47, J70, J80–J82, J85–J86, J90–J91, J93–J94, J96, J98
	Peptic ulcer disease	K25–28
	Rheumatoid arthritis	M05–M06
	Erectile dysfunction	N52.03
	Reduced fertility in women	N97
	Ectopic pregnancy	O00
	Hypertension in pregnancy (protective)	O10–O16
	Premature rupture of membranes	O42
	Placenta previa and other antepartum haemorrhage	O44, O46
	Placental abruption	O45
	Stillbirth	Z37.1, Z37.3, Z37.4, Z37.6, Z37.7
	Miscarriage	O03
	Hip Fracture	S72
	Non-Hip Fracture	S02, S12, S22, S32, S42, S52, S82, S92
	Fire injuries	X00–X01, X04–X09
	Exposure to secondhand smoke	
	Lung cancer	C34
	Otitis media	H65–H67
	Ischaemic heart disease	I20–I25
	Cerebrovascular disease	I60–I69

	Lower respiratory illness	J12–18, J20–J22
	Asthma	J45–J46
	Low birthweight	P05, P07
	Orofacial clefts	Q35–Q37
	SIDS	R95
Boachie *et al.* (2021)	Tuberculosis	A15–A19
	Other forms of heart disease	I30–I52
	Cerebrovascular diseases	I60–I69
	Hypertensive diseases	I10–I15
	Influenza and pneumonia	J09–J18
	Chronic lower respiratory diseases	J40–J47
	Ischaemic heart diseases	I20–I25
	Malignant neoplasms of digestive organs	C15–C26
	Malignant neoplasms of respiratory and intrathoracic organs	C30–C39
	Other smoking-related diseases	

**Also a SHS-associated disease and SHS-associated cause of death.*

B.2 Interpretation of smoking-attributable fraction formula

The smoking-attributable fraction (SAF) quantifies the proportion of disease burden (e.g., deaths or costs) in a population that can be attributed to smoking. The standard formula for the population attributable fraction used in this thesis is (let's assume no former smokers for simplicity):

$$SAF = \frac{p \cdot (RR - 1)}{p \cdot (RR - 1) + 1}, \tag{B.1}$$

where p is the prevalence of smoking in the population and RR is the relative risk of disease or death among smokers compared to non-smokers. This formula is commonly used in epidemiology to estimate the share of total population-level burden attributable to a specific risk factor, under the assumption of causality and independence of other risk factors.

The behavior of the SAF formula under different values of p and RR is illustrated below to clarify its interpretation.

1. When $RR = 1$ (no difference in risk between smokers and non-smokers):

$$SAF = \frac{p \cdot (1-1)}{p \cdot (1-1)+1} = 0 \tag{B.2}$$

   If smoking does not increase risk, then no burden can be attributed to smoking, regardless of its prevalence.

2. When $p = 1$ (100% of the population smokes),

$$SAF = \frac{1 \cdot (RR-1)}{1 \cdot (RR-1)+1} = \frac{RR-1}{RR} \tag{B.3}$$

   Example: if RR=10, then $SAF = 0.9$, or 90%. Even when everyone is exposed, we do not assume that 100% of the burden is caused by smoking, because there is no non-smoking baseline for comparison. The formula reflects a counterfactual: what the burden would be if everyone had the lower risk of non-smokers.

3. When $p = 0.5$ and $RR = 10$, then $SAF = 0.82$, or 82%. Even though half the population smokes, they contribute over 80% of the attributable burden due to their much higher risk. Since smokers make up a large portion of the population and have much higher risk, they account for a very large share of the total burden.

4. When $p = 0.01$ and $RR = 100$, then $SAF = 0.497$ or 49.7%. A very small exposed group (1%) with an extremely elevated risk (100x) can still account for nearly half of the total burden. This reflects the idea that even low-prevalence risk factors can have major population impacts if the relative risk is very high.

5. Limiting behavior:

   - As $p \longrightarrow 0$, $SAF \longrightarrow 0$
   - As $RR \longrightarrow \infty$, $SAF \longrightarrow p$
   - As $p \longrightarrow 1$, $SAF \longrightarrow \dfrac{RR-1}{RR}$

The SAF is a population-level measure that reflects both the prevalence of exposure and the magnitude of risk. It does not assign responsibility based on group size alone, but rather estimates the share of the total burden that could be avoided if the exposed

group had the same risk as the unexposed group. These properties are central to how SAF is interpreted in cost-of-illness studies and public health planning.

Appendix C

Appendix to Chapter 4: Business cycle sensitivity of Statutory Health Insurance: Evidence from the Czech Republic

Table C.1: AIC/BIC tests for lag selection in the baseline model

Dependent variable	***nominal GDP***	**AIC**	**BIC**
Total revenues	no lags	-248.10	-232.36
Total revenues	lag 1	-247.14	**-238.21**
Total revenues	lag 2	**-248.37**	-232.64
Total revenues	lag 3	-244.15	-235.27
Total revenues	lag 4	-237.23	-228.41
Employer-employee contributions	no lags	-260.07	-244.33
Employer-employee contributions	lag 1	-256.96	-241.32
Employer-employee contributions	lag 2	**-257.31**	**-241.57**
Employer-employee contributions	lag 3	-250.68	-235.15
Employer-employee contributions	lag 4	-245.63	-230.19
State contributions	no lags	-121.34	-105.60
State contributions	lag 1	**-122.10**	**-106.36**
State contributions	lag 2	-117.82	-102.18
State contributions	lag 3	-115.15	-99.61
State contributions	lag 4	-114.62	-99.19

Table C.2: AIC/BIC tests for lag selection in model with unemployment as BC indicator

Dependent variable	***Unemployment***	**AIC**	**BIC**
Total revenues	lag 1	-246.78	-260.73
Total revenues	lag 2	-242.43	-250.58
Total revenues	lag 3	-239.41	-255.55
Total revenues	lag 4	-233.44	-244.62
Employer-employee contributions	lag 1	-260.73	-244.99
Employer-employee contributions	lag 2	-255.55	-239.91
Employer-employee contributions	lag 3	-250.58	-235.04
Employer-employee contributions	lag 4	-244.62	-229.19
State contributions	lag 1	-120.63	-104.89
State contributions	lag 2	-117.97	-102.33
State contributions	lag 3	-114.59	-99.05
State contributions	lag 4	-112.53	-97.09

Table C.3: AIC/BIC tests for lag selection in model with industrial production as BC indicator

Dependent variable	***Industrial production***	**AIC**	**BIC**
Total revenues	lag 1	-245.62	-229.88
Total revenues	lag 2	-243.30	-227.66
Total revenues	lag 3	-246.15	-230.61
Total revenues	lag 4	-233.94	-218.51
Employer-employee contributions	lag 1	-258.34	-242.60
Employer-employee contributions	lag 2	-254.93	-239.30
Employer-employee contributions	lag 3	-253.97	-238.43
Employer-employee contributions	lag 4	-244.60	-229.17
State contributions	lag 1	-120.43	-104.69
State contributions	lag 2	-118.50	-102.86
State contributions	lag 3	-115.82	-100.28
State contributions	lag 4	-112.46	-97.03

Table C.4: AIC/BIC tests for lag selection in model with recession index as BC indicator

Dependent variable	***Recession index***	**AIC**	**BIC**
Total revenues	lag 1	-246.91	-231.17
Total revenues	lag 2	-248.24	-232.50
Total revenues	lag 3	-241.08	-225.44
Total revenues	lag 4	-237.55	-222.01
Employer-employee contributions	lag 1	-259.05	-243.31
Employer-employee contributions	lag 2	-258.75	-243.01
Employer-employee contributions	lag 3	-252.94	-237.31
Employer-employee contributions	lag 4	-249.08	-233.54
State contributions	lag 1	-120.81	-105.07
State contributions	lag 2	-121.27	-105.53
State contributions	lag 3	-117.37	-101.73
State contributions	lag 4	-114.62	-99.08

Table C.5: AIC/BIC tests for lag selection in model with BC index as BC indicator

Dependent variable	***BC index***	**AIC**	**BIC**
Total revenues	lag 1	-245.50	-229.76
Total revenues	lag 2	-245.60	-229.86
Total revenues	lag 3	-241.27	-225.63
Total revenues	lag 4	-238.30	-222.76
Employer-employee contributions	lag 1	-256.90	-241.16
Employer-employee contributions	lag 2	-258.10	-242.36
Employer-employee contributions	lag 3	-253.72	-238.08
Employer-employee contributions	lag 4	-249.77	-234.23
State contributions	lag 1	-120.60	-104.86
State contributions	lag 2	-120.33	-104.59
State contributions	lag 3	-117.42	-101.78
State contributions	lag 4	-114.60	-99.07

Table C.6: AIC/BIC tests for lag selection in model with GDP gap as BC indicator

Dependent variable	***GDP gap***	**AIC**	**BIC**
Total revenues	lag 1	-247.10	-231.36
Total revenues	lag 2	-243.67	-228.03
Total revenues	lag 3	-243.83	-228.29
Total revenues	lag 4	-233.20	-217.76
Employer-employee contributions	lag 1	-258.25	-242.51
Employer-employee contributions	lag 2	-256.98	-241.34
Employer-employee contributions	lag 3	-251.99	-236.45
Employer-employee contributions	lag 4	-244.15	-228.72
State contributions	lag 1	-121.53	-105.79
State contributions	lag 2	-117.48	-101.84
State contributions	lag 3	-114.81	-99.27
State contributions	lag 4	-112.86	-97.42

Table C.7: AIC/BIC tests for lag selection in model with CPI as BC indicator

Dependent variable	***CPI***	**AIC**	**BIC**
Total revenues	lag 1	-246.96	-231.22
Total revenues	lag 2	-241.29	-225.65
Total revenues	lag 3	-238.61	-223.08
Total revenues	lag 4	-233.11	-217.67
Employer-employee contributions	lag 1	-258.20	-242.46
Employer-employee contributions	lag 2	-253.14	-237.50
Employer-employee contributions	lag 3	-252.06	-236.52
Employer-employee contributions	lag 4	-244.17	-228.74
State contributions	lag 1	-120.28	-104.54
State contributions	lag 2	-117.38	-101.74
State contributions	lag 3	-114.65	-99.11
State contributions	lag 4	-112.53	-97.10

Table C.8: AIC/BIC tests for lag selection in model with consumer expenditure as BC indicator

Dependent variable	***Consumer expenditure***	**AIC**	**BIC**
Total revenues	lag 1	-259.09	-243.35
Total revenues	lag 2	-242.88	-227.24
Total revenues	lag 3	-240.57	-225.03
Total revenues	lag 4	-233.46	-218.02
Employer-employee contributions	lag 1	-267.77	-252.04
Employer-employee contributions	lag 2	-256.09	-240.45
Employer-employee contributions	lag 3	-252.94	-237.40
Employer-employee contributions	lag 4	-244.49	-229.06
State contributions	lag 1	-122.34	-106.60
State contributions	lag 2	-117.38	-101.74
State contributions	lag 3	-115.38	-99.85
State contributions	lag 4	-112.55	-97.12

Figure C.1: Evaluation of residuals in static model with total revenues as dependent variable

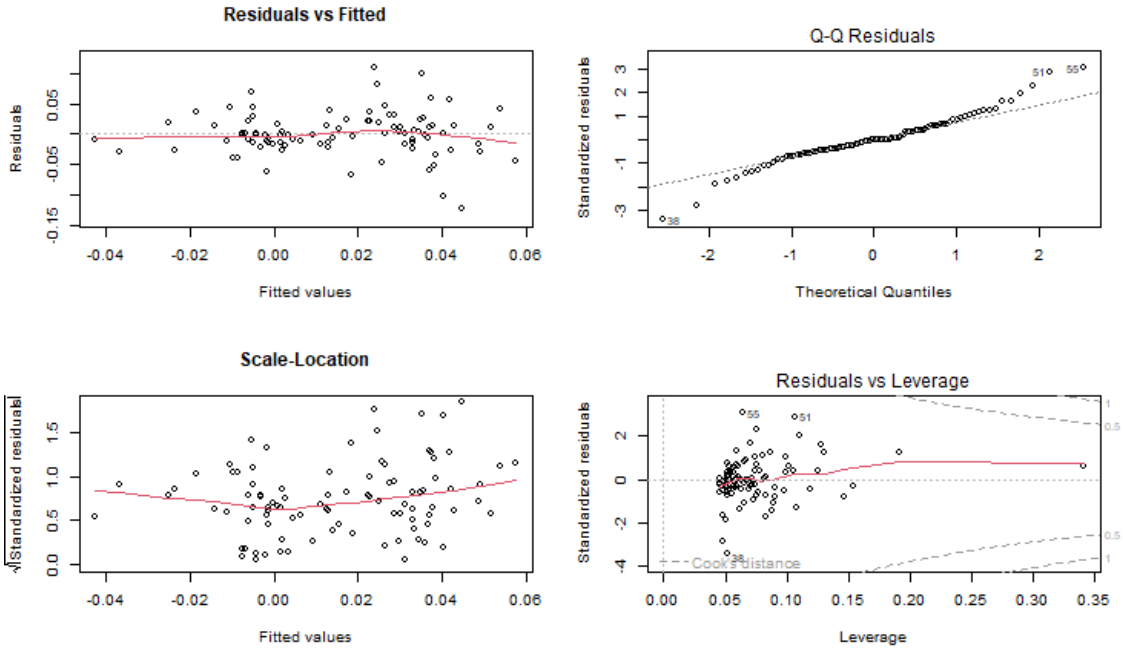


Figure C.2: Evaluation of residuals in static model with contributions from employees as dependent variable

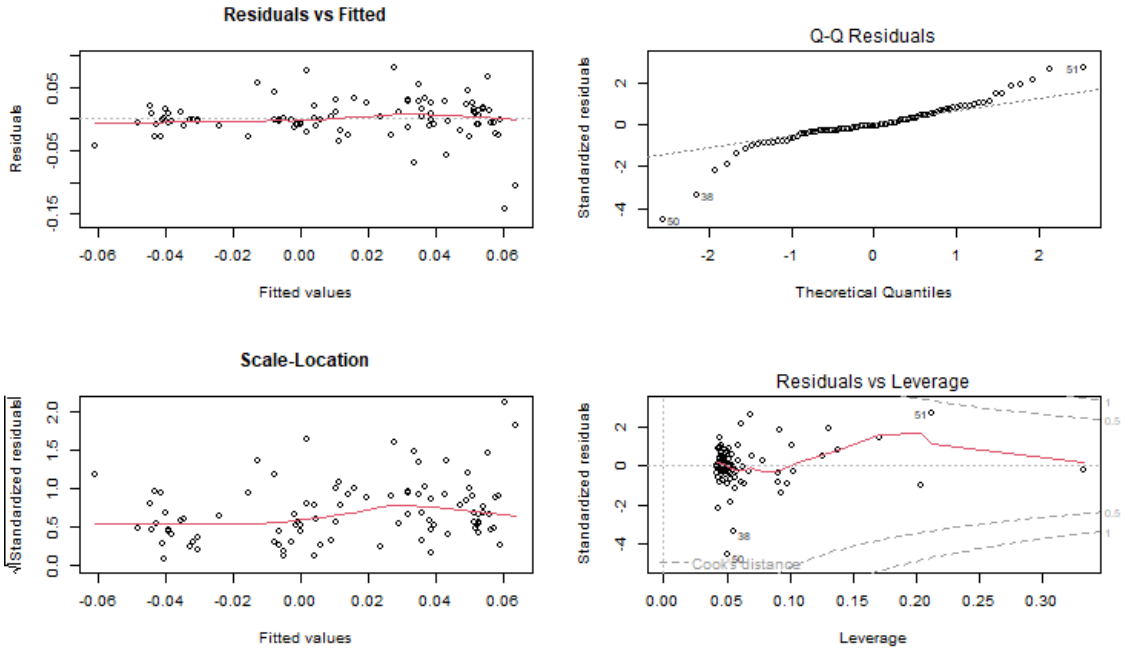


Figure C.3: Evaluation of residuals in static model with state contributions as dependent variable

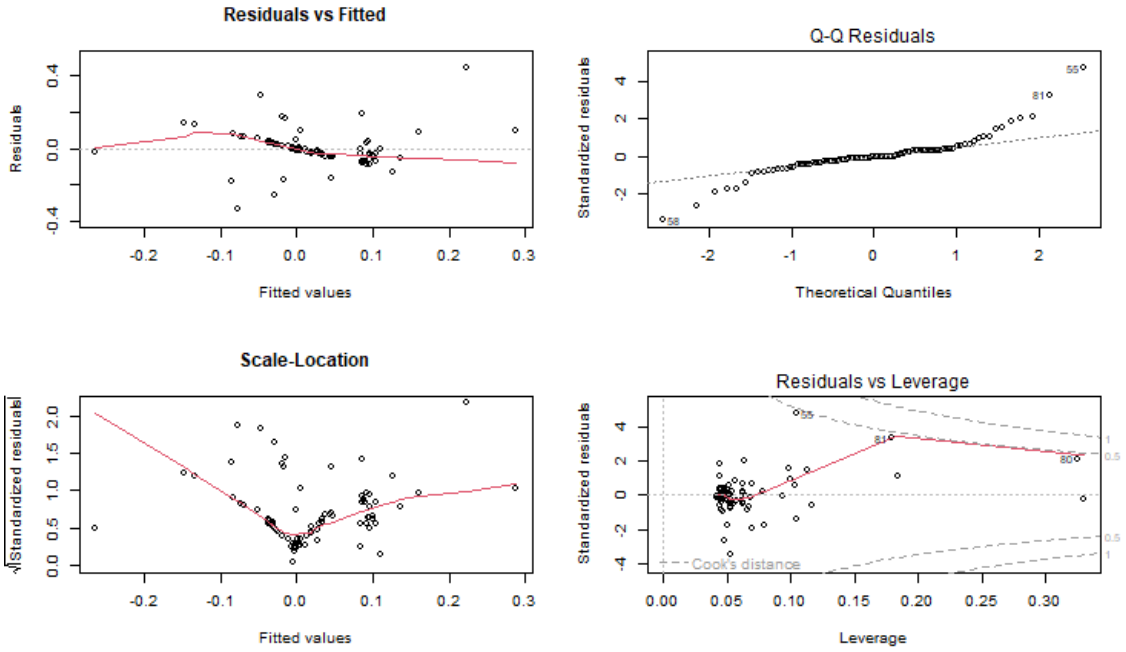


Figure C.4: Evaluation of residuals in lagged model with total revenues as dependent variable

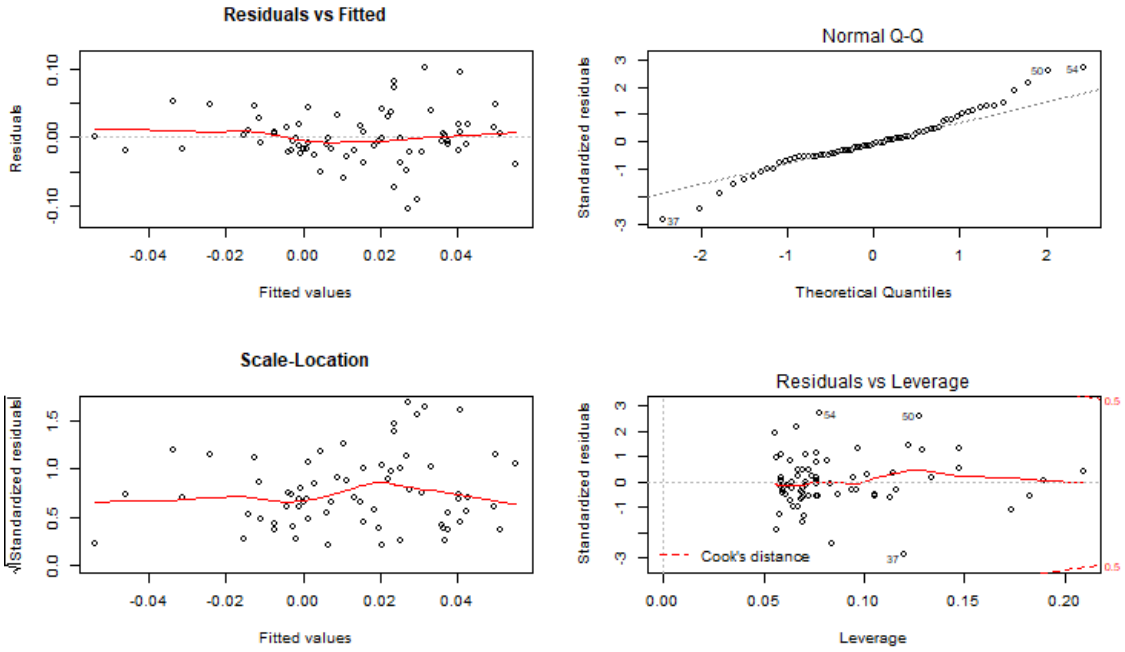


Figure C.5: Evaluation of residuals in lagged model with contributions from employees as dependent variable

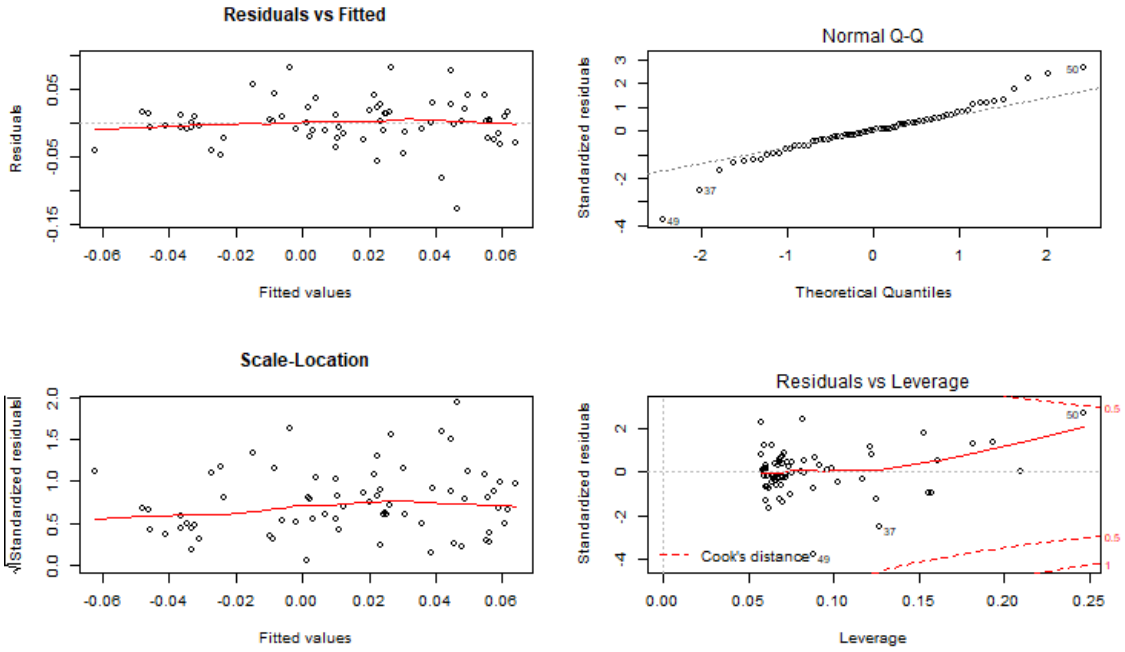
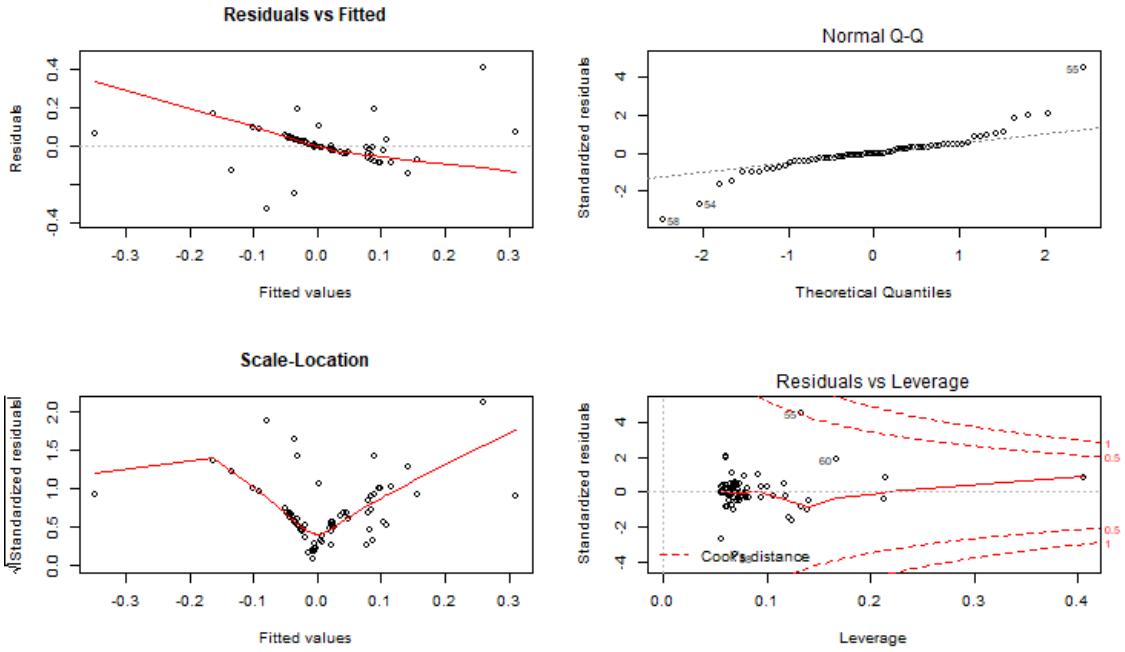


Figure C.6: Evaluation of residuals in lagged model with state contributions as dependent variable



Appendix D

Appendix to Chapter 1 and 2: Intangible costs of obesity and smoking

D.1 Introduction and motivation

This appendix presents approximate calculations of the intangible costs associated with obesity and smoking, complementing the main cost-of-illness (COI) computations reported in Chapter 1 and Chapter 2. These intangible costs capture the non-market value of pain, suffering, stigma, reduced quality of life, and premature mortality, which are typically excluded from standard COI analyses. Although often overlooked in economic evaluations, research suggests that intangible costs can rival or even exceed the more easily quantifiable direct and indirect cost components (e.g. Lievens *et al.* (2017); Whetton *et al.* (2019)).

D.2 Conceptual and methodological background

While the exclusion of intangible costs is sometimes attributed to limited data availability, there are also important conceptual reasons. Since the foundational work of Rice (1967), COI studies have typically focused on costs that can be directly measured in monetary terms, such as healthcare expenditures and productivity losses. This is partly because intangible costs are not reflected in market transactions and require strong assumptions about individual preferences, risk valuation, and willingness to pay, which can introduce substantial uncertainty into estimates.

As Rice (1967) noted on the intangible costs:

> [...] Intangible or psychic costs of disease, such as pain and grief, are omitted. These costs do not directly involve a loss of output and are not readily measurable. Several economists feel that ignoring the intangibles may distort the overall economic and social costs because the implicit assumption is that the economic value of intangible losses is zero.

As a result, most COI studies have followed the standard practice of excluding intangible costs, and their omission should be understood as reflecting the conservative nature of the approach, rather than as an indication of their insignificance. The results provided here are intended to illustrate the potential scale of this important but frequently omitted burden, offering additional context for interpreting the core findings.

D.3 Literature review

D.3.1 Obesity

A recent systematic review of 19 cost-of-obesity studies published between 2016 and 2022 (Nagi *et al.* 2024) found that none included intangible costs, confirming that their inclusion remains rare. However, two recent studies provide relevant methodological insights.

Meng *et al.* (2023) examined the intangible costs of overweight and obesity in Germany using panel data from the German Socio-Economic Panel covering 2002–2018. They applied a life satisfaction-based compensation value approach, which estimates how much income individuals would need to recover the loss in subjective well-being associated with higher BMI levels. The analysis found that in 2018, overweight individuals experienced annual intangible costs of €13 853, and obese individuals €42 450, compared to those with normal weight. A one-unit increase in BMI was associated with a well-being loss equivalent to €2 553 annually. When extrapolated to the national population, the total intangible costs of overweight and obesity were calculated at approximately €4.3 billion.

A broader framework was adopted by Barton & Love (2021) in New Zealand, where intangible costs of high BMI (defined as BMI $\geq$ 25) were estimated using DALYs attributable to obesity from the 2019 Global Burden of Disease (GBD) Study. The total burden was estimated at 64 447 to 135 994 DALYs, with a central estimate of 98 852 DALYs lost in 2019. Three alternative monetization approaches were applied. First, DALYs were valued

using Pharmac's cost-effectiveness threshold (NZD $32 258 per QALY gained), producing a lower-bound estimate of intangible costs equal to NZD $2.1–4.4 billion. Second, the WHO-CHOICE threshold method applied 1–3 times New Zealand's GDP per capita (NZD $63 444), resulting in a broader range of NZD $4.1–25.9 billion. Finally, a WTP approach based on the VSLY was used, where the VSLY was derived from a national VSL of NZD $4.56 million, discounted over life expectancy to obtain NZD $193 737 per life year. This yielded the highest estimate: NZD $12.5–26.3 billion in intangible costs. Altogether, intangible costs potentially represented between 10% and 58% of the total economic burden of obesity in New Zealand, depending on the valuation method applied.

D.3.2 Smoking

Only a handful of COI studies include estimates of intangible costs, despite their potentially large contribution to the overall burden. A systematic review by Makate *et al.* (2020) covering 64 studies notes that "most analyses were restricted to direct (e.g. inpatient care) and indirect (e.g. lost value of productivity) tangible costs and did not include intangible costs such as those arising from premature mortality or from living with a smoking-related disease."

Several studies from Australia provide exceptions. Collins & Lapsley (2008) estimate the intangible costs of tobacco use in Australia for 2004/05 by valuing the psychological cost of premature mortality using a demographic approach. Rather than applying a value of statistical life, they estimate the value of a year of life lost at AUD $53 267, based on earlier Bureau of Transport Economics recommendations. This value is multiplied by the number of years of life lost (YLL) due to smoking-attributable deaths. The resulting intangible costs totaled AUD $19.5 billion and represented 61.8% of the total estimated burden of smoking.

In a follow-up study for New South Wales, Collins & Lapsley (2010) applied the same demographic method to state-level data for 2006/07. Using the same per-year value of life lost, they estimated intangible costs at AUD $5 458 million, which made up 65% of the total costs in New South Wales. Both studies reflect a conservative willingness-to-pay approach focused solely on mortality-related losses, excluding pain or suffering from illness.

Whetton *et al.* (2019) adopted a broader framework by estimating both morbidity and mortality-related intangible costs. They quantified years lived with disability (YLD)

attributable to 29 smoking-related diseases using GBD data and assumed that the proportion of YLDs attributable to smoking mirrored the share of hospital separation costs attributable to smoking for each disease. The YLDs were monetized using a VSLY, while mortality was valued using a standard VSL of AUD $4.6 million. This produced intangible costs of AUD $25.6 billion for morbidity and AUD $92.1 billion for mortality, representing 86% of total costs.

In Belgium, Lievens *et al.* (2017) used the DALY approach to quantify intangible costs of smoking for 2012. They retrieved disease-specific DALY estimates by age and sex from the WHO GBD database and multiplied them by a monetary value of €40 000 per DALY. This produced intangible costs of €11.8 billion. The direct and indirect (tangible) costs were estimated at €1.473 billion, meaning intangible costs represented 88.8% of the total burden.

D.4 Quantification of intangible costs in this study

To provide a more complete view of the economic burden of smoking and obesity, this study calculates intangible costs using three alternative approaches: QALYs, DALYs, VSL and VSLY. These results are not included in the core COI calculations but serve as illustrative upper bounds.

D.4.1 QALY-based results (obesity)

For obesity-related morbidity, we draw on the work of Jia & Lubetkin (2010), who estimated that U.S. individuals with obesity experience an average loss of 0.0464 QALYs per year, of which 0.0265 are attributable to morbidity. To improve precision, we use their gender-specific estimates: 0.013 QALYs lost annually among obese men and 0.026 among obese women. These figures reflect reduced health-related quality of life due to obesity-related chronic conditions. Using Czech population data from 2018 (approximately 1.13 million obese men and 1.15 million obese women), and the national valuation of CZK 1.2 million per QALY (as recommended by the State Institute for Drug Control), we calculate the total intangible burden due to morbidity at:

- 0.7 billion EUR (17.6 billion CZK) for men, and
- 1.4 billion EUR (40.0 billion CZK) for women,

yielding a combined costs of 2.1 billion EUR (53.6 billion CZK). This corresponds to 57% of the total costs of obesity.

D.4.2 VSL-based results (obesity and smoking)

To calculate the intangible costs of premature mortality, we use the most recent estimates of the VSL for the Czech Republic from Alberini & Ščasný (2021). These are based on two contingent valuation surveys (conducted in 2014 and 2019) that assessed respondents' willingness to pay for cancer mortality risk reductions. The resulting VSL estimates range from €2.999 million to €4.216 million, expressed in 2019 purchasing power parity euros. Adjusting for inflation using Eurostat consumer price indices (Eurostat 2018b), we calculate the VSL in 2018 as 2.924–4.111 million EUR.

Applying this range to the calculated number of obesity- and smoking-attributable deaths in the Czech Republic:

- 12 505 obesity-attributable deaths result in intangible costs of 36.6–51.4 billion EUR, or 95.8–97.0% of total obesity-related costs,
- 14 875 smoking-attributable deaths yield costs of 44.6–62.7 billion EUR, or 95.5–96.7% of smoking-related costs.

While VSL is a widely accepted tool in policy evaluation, it does not distinguish by age or life expectancy. An alternative is the value of a statistical life year (VSLY), which multiplies expected years of life lost by a per-year value. As highlighted by Hammitt (2023), the age-invariant nature of VSL may introduce biases across age groups, but it nonetheless offers a conservative and standardized benchmark for computing mortality-related intangible costs.

D.4.3 VSLY-based results (obesity and smoking)

To complement the main results based on the VSL, this section presents intangible cost results derived from the value of a statistical life year (VSLY). This approach expresses the cost of premature mortality as the product of years of life lost (YLL) and a value per life year, offering a conceptually distinct and often more granular alternative to VSL-based results, accounting for the age structure of deaths.

Methodology

The VSLY can be computed in several ways. The simplest method divides the VSL by the average YLL:

$$\text{VSLY}_{\text{undisc}} = \frac{\text{VSL}}{\text{Average YLL}}$$

We also present discounted versions using a standard annual discount rate of 3%, and we include an international benchmark approach assuming a standard YLL of 40 years (Whetton *et al.* 2019). We calculated that 129 552 years of life were lost due to obesity and 227 098 years of life were lost due to smoking.

Obesity

For obesity-attributable deaths, the average YLL is computed at 10.4 years based on our computations. Using a VSL of €4.11 million in 2018 and €4.216 million in 2019 (Alberini & Ščasný 2021), the following values are obtained:

- **Undiscounted:**

$$\text{VSLY}_{\text{undisc}} = \frac{4{,}110{,}404}{10.4} \approx \text{EUR } 395{,}231$$

$$\text{Total Cost}_{\text{undisc}} = 129{,}552 \times 395{,}231 \approx \text{EUR } 51.2\,\text{billion}$$

- **Discounted (3% over 10.4 years):**

$$\text{PV}_{10.4} \approx 8.822^{1} \quad \Rightarrow \quad \text{VSLY}_{\text{disc}} = \frac{4{,}110{,}404}{8.822} \approx \text{EUR } 465{,}941$$

$$\text{Total Cost}_{\text{disc}} = 129{,}552 \times 465{,}941 \approx \text{EUR } 60.4\,\text{billion}$$

[1]We aim to derive the present value PV of an annuity that pays 1 unit of currency each year for T years, discounted at a constant rate r. The present value is defined as: $PV = \sum_{t=1}^{T} \frac{1}{(1+r)^t}$. This is a finite geometric series. To simplify the sum, we first rewrite it by changing the index to start from 0: $PV = \sum_{t=1}^{T} \frac{1}{(1+r)^t} = \sum_{t=0}^{T-1} \frac{1}{(1+r)^{t+1}} = \frac{1}{1+r} \sum_{t=0}^{T-1} \left(\frac{1}{1+r}\right)^t$. We now apply the standard formula for the sum of a finite geometric series: $\sum_{t=0}^{T-1} q^t = \frac{1-q^T}{1-q}$. Substituting $q = \frac{1}{1+r}$, we get: $PV = \frac{1}{1+r} \cdot \frac{1-\left(\frac{1}{1+r}\right)^T}{1-\frac{1}{1+r}} = \frac{1}{1+r} \cdot \frac{1-(1+r)^{-T}}{\frac{r}{1+r}}$. Simplifying the expression: $PV = \frac{1-(1+r)^{-T}}{r}$. This is the final formula used to compute the present value of receiving 1 unit of currency each year for T years, discounted at rate r. Substituting $T = 10.4$ and $r = 0.03$, we get $PV \approx 8.822$.

- **Discounted with 40-year benchmark:**

$$\text{PV}_{40} \approx 23.11 \quad \Rightarrow \quad \text{VSLY}_{\text{disc, 40yr}} = \frac{4{,}110{,}404}{23.11} \approx \text{EUR } 177{,}826$$

$$\text{Total Cost}_{\text{disc, 40yr}} = 129{,}552 \times 177{,}826 \approx \text{EUR } 23.0 \text{ billion}$$

In summary, the intangible costs of obesity calculated using VSLY amount to 23.0–60.4 bn EUR, representing 93.5–97.4% of total costs.

Smoking

For smoking-attributable deaths, the average YLL is 15.3 years based on our computations. Using the same VSL, we obtain:

- **Undiscounted:**

$$\text{VSLY}_{\text{undisc}} = \frac{4{,}216{,}000}{15.3} \approx \text{EUR } 276{,}151$$

$$\text{Total Cost}_{\text{undisc}} = 227{,}098 \times 276{,}151 \approx \text{EUR } 62.71 \text{ billion}$$

- **Discounted (3% over 15.3 years):**

$$\text{PV}_{15.3} \approx 12.13 \quad \Rightarrow \quad \text{VSLY}_{\text{disc}} = \frac{4{,}216{,}000}{12.13} \approx \text{EUR } 347{,}659$$

$$\text{Total Cost}_{\text{disc}} = 227{,}098 \times 347{,}659 \approx \text{EUR } 78.95 \text{ billion}$$

- **Discounted with 40-year benchmark:**

$$\text{VSLY}_{\text{disc, 40yr}} = \frac{4{,}216{,}000}{23.11} \approx \text{EUR } 182{,}394$$

$$\text{Total Cost}_{\text{disc, 40yr}} = 227{,}098 \times 182{,}394 \approx \text{EUR } 41.42 \text{ billion}$$

The intangible costs of smoking computed using VSLY amount to 41.4–79.0 bn EUR, representing 95.1–97.4% of total costs.

As summarized in Table D.1, the undiscounted VSLY approach replicates the standard VSL-based results. Discounting increases the per-year value, and applying a 40-year benchmark yields more conservative results. These results underscore the sensitivity of intangible costs to methodological assumptions.

Table D.1: Comparison of VSLY-based intangible cost results (EUR)

Condition	Method	VSLY (EUR)	Total Cost (bn EUR)
Obesity	Undiscounted (YLL = 10.4)	395,231	51.2
	Discounted (YLL = 10.4)	465,941	60.4
	Discounted (YLL = 40)	177,826	23.0
Smoking	Undiscounted (YLL = 15.3)	276,151	62.71
	Discounted (YLL = 15.3)	347,659	78.95
	Discounted (YLL = 40)	182,394	41.42

D.4.4 DALY-based results (obesity and smoking)

We also apply the DALY framework to calculate intangible costs, using GBD 2019 data for the Czech Republic. The number of DALYs attributable to smoking and obesity is calculated by combining gender-specific DALYs with PAFs for obesity or SAFs for smoking for each condition. To identify relevant diseases, we manually matched GBD disease categories to the risk-specific conditions listed in Table 2.1 (for smoking) and Table 1.5 (for obesity), based on disease names rather than ICD-10 codes, which are not available in the GBD dataset.

For obesity, we include 15 diseases[2] that match the conditions listed in Table 1.5. Applying gender-specific DALY data and PAFs, we compute 174 810 DALYs attributable to obesity in men, and 222 060 in women[3]. Following Kříž (2016), who notes that while an official value of a DALY has not yet been established in the Czech Republic, existing analyses commonly use a benchmark of 800 000 CZK per DALY, we adopt this value as the baseline figure for our calculations. The intangible costs are equal to 12.4 billion EUR (317.5 billion CZK), which represent 89% of the total costs of obesity[4].

For smoking, we include 18 conditions[5], comprising 17 disease categories and 1 ex-

[2]Included conditions: asthma, back and neck pain, diabetes mellitus, ischemic heart disease, leukaemia, malignant skin melanoma, ischemic stroke, osteoarthritis, kidney cancer, breast cancer, pancreas cancer, colon and rectum cancers, ovary cancer, gallbladder and biliary tract cancer, and hypertensive heart disease.

[3]For comparison, Zhou *et al.* (2024) estimated the DALYs attributable to high BMI (defined as BMI $\geq$ 25) in 2021, the figure for the Czech Republic was 359 381 (144 329–585 388 DALYs).

[4]For comparison, if the QALY value of 1.2 million CZK were applied instead, assuming equal valuation of QALYs and DALYs, the resulting values would be 50% higher. This adjustment would apply to both the intangible costs of obesity and smoking.

[5]Included conditions: lip and oral cavity cancer, other pharynx cancer, oesophagus cancer, stomach cancer, colon and rectum cancers, liver cancer, pancreas cancer, trachea/bronchus/lung cancer, cervix

ternal cause of death. Based on GBD 2019 data and applying gender-specific SAFs, we calculate 298 290 DALYs attributable to smoking among men, and 143 710 among women. Using a Czech-specific valuation of 800 000 CZK per DALY (Kříž 2016), this results in total intangible costs of 13.77 billion EUR (353.6 billion CZK), which accounts for 87% of the total costs of smoking.

D.5 Summary and discussion

The results of the intangible costs due to obesity and smoking are summarized in Table D.2. These costs are not included in the main cost-of-illness results but are presented here to illustrate the potentially large burden typically excluded from standard economic evaluations. Depending on the valuation method, intangible costs represent between 57% and 97% of total costs, significantly exceeding the tangible burden. If these intangible costs were included, the total costs of obesity would account for 1.83–30.11% of GDP in 2018, and the total costs of smoking would account for 7.04–35.93% of GDP in 2019 (see Table D.3). These findings underscore the importance of adopting a broader perspective in health economic assessments.

Table D.2: Tangible and intangible costs of obesity and smoking by method

Method	**Tangible costs (bn EUR)**	**Intangible costs (bn EUR)**	**Share of intangible costs (%)**
Obesity			
VSL	1.6	36.6–51.4	95.8–97.0%
VSLY	1.6	23.0–60.4	93.5–97.4%
DALY	1.6	12.4	89.0%
QALY	1.6	2.1	57.0%
Smoking			
VSL	2.1	44.6–62.7	95.5–96.7%
VSLY	2.1	41.4–79.0	95.1–97.4%
DALY	2.1	13.8	87.0%

uteri cancer, ovary cancer, kidney cancer, larynx cancer, leukaemia, diabetes mellitus, ischemic heart disease, chronic obstructive pulmonary disease, and fire-related injuries.

Table D.3: Tangible and intangible costs of obesity and smoking

Risk factor	**Tangible costs (bn EUR)**	**Intangible costs (bn EUR)**	**% of GDP**
Obesity	1.6	2.28–61.9	1.83–30.11
Smoking	2.1	13.8–79.0	7.04–35.93

Appendix E

Response to reviewers

Firstly, I would like to thank my supervisor, Doc. PhDr. Martin Gregor, Ph.D., as well as all three referees for the time and effort they devoted to reading my dissertation and preparing their reports. I am sincerely grateful for their valuable comments and suggestions. Although the opponents did not request substantial changes, several revisions have been made in response to comments raised by Mgr. Milan Ščasný, Ph.D. Specifically, the introduction has been expanded to include a new section on the Health Production Function, and a new Appendix D has been added to illustrate the magnitude of intangible costs using multiple approaches. Detailed responses to the opponents' comments and to Dr. Ščasný's suggestions are provided below. In summary, all comments have been addressed and incorporated into the final version of the thesis.

E.1 Advisor's report on Dissertation Thesis

Doc. PhDr. Martin Gregor Ph.D., Institute of Economic Studies, Charles University

Overview of the thesis

The thesis analyzes social costs of smoking and obesity in the Czech health system and, additionally, examines the sensitivity of the revenue side of healthcare financing to the business cycle. All three topics are highly policy-relevant and Petra approached them with relevant empirical techniques.

All three essays contain work that has been already published in respectable journals, specifically in the *European Journal of Health Economics* (AIS 1.29, co-authored with

Martina Karbanová), *Applied Health Economics and Health Policy* (AIS 1.046, solo-authored), and the *Health Economics Review* (AIS 0.885, solo-authored). All three journals are listed in the categories "Economics" and "Health Policy & Services" in Web of Knowledge. (In addition, Applied Health Economics and Health Policy is also listed in "Health Care Sciences & Services".)
Having published all three dissertation chapters in three different well-recognized international journals is undoubtedly an achievement and a signal of a very good job.

A broader assessment of Petra's dissertation-related work
Petra was a showcase of a well-motivated and hard-working student. She closely combined her dissertation work with policy analysis at the institute called Czech Priorities which greatly contributed to the policy relevance of the thesis. Importantly, this combination helped her stay focused and motivated and gave her an opportunity to receive additional feedback on her work.
Petra served as a teaching assistant in the Intermediate Microeconomics I and II courses. She reviewed multiple undergraduate theses, especially theses in a growing field of health economics but also other theses in public economics and public policy. Throughout her studies, she submitted a couple of grant applications but, given very intensive competition, none of her applications was funded. I helped her with some small funding through my research budget.
In terms of collaboration, she was always diligent, careful, and highly responsive. Her timeline in writing the thesis was exemplary, given that she also managed to give birth to two kids. I was always impressed to see how well-organized she was when doing her dissertation work, both in the early as well as in the late stages of the publishing process.

Recommendation
I have extensively discussed the thesis with Petra. All my comments have already been incorporated, so I have no comments or suggestions for improvements.

Therefore, I gladly recommend the thesis for defense without substantial changes.

E.2 Opponent's Report on Dissertation Thesis

Prof. Cinzia Di Novi Ph.D, University of Pavia

a) Can you recognize an original contribution of the author?
The thesis provides an original and policy-relevant contribution to health economics by quantifying the economic burden of obesity and smoking in the Czech Republic and analysing the pro-cyclicality of statutory health insurance (SHI) revenues. The candidate's work on the social costs of smoking, conducted as a single-author study, further demonstrates her independent research capabilities. Additionally, the analysis of the economic cycle's impact on SHI financing offers valuable insights for policymakers, highlighting the need for counter-cyclical mechanisms to stabilize healthcare funding.
b) Is the thesis based on relevant references?
The thesis builds on relevant references, employing the cost-of-illness (COI) method– a widely used approach in health economics–to assess the economic burden of obesityand smoking. The discussion of COI's limitations is well-supported by academic sources, including references to established methodological critiques. The analysis of SHI revenue sensitivity is also informed by relevant economic and policy literature.
c) Is the thesis defendable at your home institution or another respected institution where you gave lectures?
In my opinion, the thesis meets the academic standards required for a PhD dissertation in health economics. Its empirical rigor, methodological soundness, and policy relevance make it defendable at my home institution or other respected academic institutions. The candidate demonstrates the ability to conduct independent research, publish in international journals, and contribute to policy discussions in the field.
Do the results of the thesis allow their publication in a respected economic journal?
Two of the three chapters have already been published in internationally recognized health economics journals (The European Journal of Health Economics and Applied Health Economics and Health Policy), attesting to their quality and relevance. The third chapter, which analyses the economic cycle's impact on SHI, has received a Revise & Resubmit decision from Health Economics Review, indicating its potential for publication.
d) Are there any additional major comments on what should be improved?
I would suggest a few minor revisions to enhance the clarity and completeness of the thesis:

1. **Clarifying the Introduction of Chapter 3.** The introduction should provide a clearer definition of SHI scheme sensitivity and elaborate on why this topic is relevant. Expanding the first two lines with additional context would improve the framing of the research.

Thank you for this suggestion. I have expanded the first paragraph in the following way:
Achieving sustainable financing of the healthcare sector is challenging in the context of aging populations and health and economic shocks. Adequate funding is essential to ensure the long-term sustainability of healthcare systems and to maintain the availability and affordability of health services. One key aspect of financial stability is the extent to which healthcare financing mechanisms are sensitive to economic fluctuations. In this chapter, we focus on the business cycle sensitivity of Statutory Health Insurance (SHI) schemes, which are one of the two dominant healthcare financing models in the European Union, alongside general taxation-based systems (Jakubowski, 1998). The term "business cycle sensitivity" refers to the responsiveness of SHI revenues to macroeconomic conditions, particularly fluctuations in employment, wages, and overall economic activity. Since SHI schemes are predominantly funded through payroll-based contributions, economic downturns may lead to revenue shortfalls, potentially challenging the financial sustainability of healthcare provision. Although the relationship between the business cycle and healthcare system revenues has been frequently discussed, it has not yet been systematically quantified for either SHI (Bismarck model) or general taxation (Beveridge model) schemes. This study aims to fill this gap by providing empirical evidence on the extent to which SHI revenues fluctuate with economic conditions and assessing the implications for healthcare system resilience.

2. **Contextualizing the Czech Healthcare Model.** A dedicated section on the Czech healthcare system's structure and financing mechanisms would help readers unfamiliar with the topic better understand the empirical analysis in Chapter 3.

Thank you for this helpful suggestion. I agree that providing additional context will strengthen the chapter, especially for readers who may be less familiar with the Czech healthcare system. To address this, I have added a new section (Section 3.2) in Chapter 3 that offers a brief overview of the institutional and financial structure of the system.

3. **Conclusions. Addressing COI Limitations:** While the discussion of COI's limitations is well-developed, I recommend further addressing the exclusion of intangible costs, either in the thesis conclusions or, if possible, within the individual chapters.

Thank you for bringing this up. A similar note has been raised by a member of the committee during pre-defense and consequently, a new Appendix D has been added to the thesis, containing basic computations of intangible costs to illustrate their magnitude. However, the intangible costs are still excluded from the core computations, so a discussion addressing the exclusion of intangible costs has been added in each chapter's discussion:
Chapter 1: *... Thirdly, the core results of this study do not account for intangible costs and disutility, that is, the non-monetary burdens of illness such as pain, suffering, and reduced quality of life. While these components are significant from both societal and individual perspectives, their inclusion in COI studies remains relatively uncommon since the original development of the framework by Rice (1967). In theoretical models such as the Health Production Function, disutility is recognized as a distinct and important component of the total economic burden of illness. Intangible costs and disutility are typically valued using methods such as WTP surveys or monetized QALYs and DALYs, which are well-established in welfare economics and health technology assessment. However, these approaches are not standard practice in cost-of-illness studies, which traditionally focus on direct and indirect costs measurable through healthcare and labor market data. To maintain consistency with the broader COI literature and focus the analysis on tangible economic impacts, these components are excluded from the main results. Nonetheless, to illustrate their potential magnitude, an indicative estimate is provided in Appendix D.*

Chapter 2: *... Fourth, the results presented in this chapter do not include the costs of SHS exposure or intangible costs, which implies that the total economic burden of smoking is likely underestimated. SHS exposure is associated with substantial health risks and corresponding costs, but due to the absence of reliable population-level data on exposure and outcomes in the Czech Republic, these costs could not be robustly quantified within the scope of this study. Intangible costs, such as pain, suffering, and reduced quality of life, are also excluded from the core estimates. These costs are highly relevant from a societal and welfare-economic perspective, and are typically valued using methods such as WTP or QALYs. However, intangible costs are still rarely included in cost-of-illness studies, which have historically focused on direct healthcare costs and productivity losses. To ensure compara-*

bility with the existing COI literature and maintain a consistent methodological focus, this chapter follows the conventional approach of excluding intangible costs from the main results. Nonetheless, an illustrative estimate of the potential magnitude of intangible costs associated with smoking is provided in Appendix D to offer a broader perspective on the societal burden.

Furthermore, a note has been added to Conclusion of the whole thesis:
The first two essays quantify the economic burden of obesity and smoking, two risk factors that are associated with higher risk of developing non communicable diseases such as cardiovascular diseases or some forms of cancer, which brings large socioeconomic costs. Employing the cost-of-illness (COI) framework, these studies provide comprehensive evaluations of both direct costs, such as healthcare expenditures, and indirect costs, including productivity losses due to absenteeism, presenteeism, and premature mortality. The findings highlight the substantial economic burden posed by these preventable conditions, emphasizing the need for targeted preventive interventions to re duce prevalence and associated costs. By adopting robust methodologies and incorporating sensitivity analyses, these essays also demonstrate the importance of methodological rigor in estimating economic impacts and informing policy decisions. These essays fill a significant gap in the literature, providing the first comprehensive estimates for these public health issues in the Czech Republic. It is important to note that the results should be interpreted as lower-bound values, as the analyses focus only on the first two components of the Health Production Function: the direct medical costs and productivity losses. Disutility and intangible costs, such as pain, suffering, and diminished quality of life, are excluded from the main calculations but are likely to be substantial.

4. **Structuring the Thesis Conclusion** – I would suggest labeling the final section as Conclusions rather than Chapter 5 and similarly refraining from numbering the general introduction as Chapter 1, as it does not function as a standalone chapter.

Thank you for this suggestion, I have relabelled Chapter 1 as Introduction and Chapter 5 as Conclusion.

f) What is your overall assessment of the thesis?
The PhD thesis of candidate Petra Landovska consists of three chapters addressing distinct yet highly policy-relevant topics in health economics, specifically within the context of the Czech Republic: the social costs of obesity, the economic burden of smoking, and

the vulnerabilities of revenue in the statutory health insurance (SHI) system.
The first two essays employ the cost-of-illness (COI) method to quantify the economic burden of obesity and smoking. These studies have been published in reputable international journals in the field namely: The European Journal of Health Economics and Applied Health Economics and Health Policy. Notably, the second essay, which examines the social costs of smoking in the Czech Republic as a single-author paper, demonstrates the candidate's ability to conduct independent research, despite her relatively early academic stage.
The third essay analyses the impact of the economic cycle on SHI revenues, highlighting their pro-cyclicality and vulnerability during economic downturns. The findings emphasize the importance of counter-cyclical mechanisms to stabilize healthcare system funding. This work is currently available as a working paper under single authorship and has received a Revise & Resubmit decision from the journal Health Economics Review (Landovska, P. (2020). Business Cycle Sensitivity of Statutory Health Insurance: Evidence from the Czech Republic (No. 2020/33). Charles University Prague, Faculty of Social Sciences, Institute of Economic Studies).
The first chapter of the thesis focuses on obesity, a major global health issue with rising prevalence rates. The author highlights that the Czech Republic represents a particularly relevant case, given the significant increase in obesity rates since the 1990s among both adults and children. As obesity is a key risk factor for numerous chronic diseases (including type 2 diabetes, cardiovascular diseases, and certain cancers) the study estimates its social costs using the COI method. This approach, at least in principle, quantifies the economic burden of obesity by incorporating various cost categories. A similar approach is applied to estimate the social costs of smoking, widely recognized as one of the most significant preventable health risks, leading to increased mortality from cardiovascular diseases and cancers (including but not limited to lung cancer).
While these two chapters are well-written and methodologically sound, it is important to acknowledge the inherent limitations of the COI method. The COI approach generally includes three cost categories: direct costs, indirect costs, and intangible costs, integrating both market- based and non-market valuation techniques. Direct costs refer to market-based expenditures such as medications, diagnostic tests, healthcare personnel, and hospital facilities. Indirect costs, also known as productivity costs, account for: (i) losses due to reduced productivity or impaired work capacity caused by illness, and (ii) productivity losses resulting from premature mortality. Intangible costs, on the other

hand, represent non-market resources and reflect the pain and suffering experienced by patients, as well as the impact on their quality of life. A major limitation of the COI method is the frequent exclusion of intangible costs, as is the case in this study. Estimating these costs typically relies on individuals' willingness to pay (WTP), which can be challenging and imprecise. Since the full economic burden of illness includes not only productivity losses and out-of-pocket expenses but also pain, suffering, and reduced leisure time, COI estimates often provide only a lower bound of the true monetary value of health effects (Pervin, T., Gerdtham, U. G., & Lyttkens, C. H. (2008). Societal costs of air pollution- related health hazards: A review of methods and results. Cost Effectiveness and Resource Allocation, 6, 1-22). This issue warrants further exploration - if not within the individual chapters, given their prior publication, then in the concluding section of the thesis.

On this note, I suggest labeling the final section simply as Conclusions rather than Chapter 5, and similarly, refraining from designating the general introduction as Chapter 1, as it does not function as a standalone chapter.

Regarding the third chapter, I have one main suggestion: I recommend adding a dedicated section, even a brief one, to describe the key characteristics of the Czech healthcare system. This would provide additional context beyond what is presented in the introduction and help the reader better understand the empirical analysis. Furthermore, in the introduction, I would suggest clarifying from the outset what is meant by the sensitivity of SHI schemes and expanding the first two lines with additional details on the relevance of this topic. The Czech healthcare system is primarily financed through a public health insurance model (SHI), which relies on wage-based contributions from workers and employers. This makes it vulnerable to economic downturns, when rising unemployment leads to declining revenues. As public health insurance funding is closely tied to economic fluctuations, its sustainability can be jeopardized during financial crises. Making these points more explicit in the introduction would strengthen the thesis's overall framing.

I recommend the thesis for defence without substantial changes.

E.3 Opponent's Report on Dissertation Thesis

Andrea Menclova Ph.D., University of Canterbury

Thank you for the opportunity to read this PhD thesis. I found the research interesting, relevant and competently conducted. I also appreciate how well the thesis is written. A thesis of this standard would satisfy the norms of my home institution.

Chapter 1
The introductory chapter provides a useful overview of the thesis and ties individual chapters together in a coherent whole. The introduction is well-written and engaging. It is also great to see that all three substantive chapters of the thesis have already been published (two in Scimago Q1 journals and one in Q2 – all very respectable).
A strength of Chapter 1 is that it provides a balanced overview of various methods used in the literature and identifies the methods selected for the thesis. This elegantly and transparently places the thesis within the wider literature. However, in a few instances, I would appreciate more emphasis on why particular methods were selected over other ones. As it currently stands, the chapter lists pros and cons of each method but stops somewhat short of giving them weights or justifying the author's final choice among them. For example, the discussion of the 'econometric approach' concludes with: "[...] the econometric approach is more data-efficient and often requires only one dataset, making it advantageous in many scenarios" (p.8) An additional concluding sentence explaining why this 'advantageous' approach was not selected would be helpful.

Thank you for pointing this out. I have added the following two paragraphs in the Introduction to explain the choice of the methodology for the estimation of direct and indirect costs:
The top-down approach is implemented to estimate the direct costs of obesity and smoking, based on 2018 obesity prevalence, 2019 smoking prevalence in the Czech Republic, and Relative Risks (RRs) values from existing literature. This choice is primarily driven by data availability. Implementing a bottom-up or econometric approach would require patient-level data, which is not accessible in the Czech Republic. Although health insurance funds do collect data on individual healthcare consumption, these records do not include information on patients' BMI or smoking status. Additionally, health insurance funds are generally un-

willing to share their data. Conducting a dedicated survey would be necessary to obtain the information required for the econometric or bottom-up approach.
In this thesis, the HCA is used to estimate indirect costs in the baseline model, as it remains the most widely applied method in COI studies and is suitable for descriptive burden-of-illness analysis. Its application is also driven by data constraints in the Czech Republic, where essential inputs for implementing a full WTP analysis, such as detailed preference-based risk valuations for obesity or smoking, are not readily available. Nevertheless, it is acknowledged that HCA-based valuations do not conform to the welfare economic framework, which favors WTP-based estimates such as the VSL. As such, the results presented here should be interpreted as a lower-bound estimate of the total societal burden. For smoking, the FCA is additionally applied in sensitivity analysis to demonstrate how cost estimates vary with alternative methods and to partially address the critique that the HCA does not account for labor substitution.

Minor (roughly in the order of importance):

- Page 10: "the FCA is seen as a useful upper bound" – I believe this should be 'lower bound'

  Thank you for pointing this out, the text has been changed.

- Page 7: "measures the proportion of a disease that is due to exposure to the disease" – please make it clear that this sentence refers to two different diseases (later called disease A and disease B)

  Thank you for this note, the text has been changes to "The top-down approach, also known as the epidemiological or attributable risk approach, measures the proportion of a disease B that is due to exposure to the disease or risk factor A (for example, large part of costs of diabetes is attributable to obesity)" to make it clearer.

- Page 7: "the prospective approach is thus more expensive" – 'approach' (or another appropriate noun) missing.

  Thank you, the missing noun has been added.

- Page 3: "the 2008 crisis" – please be more specific (e.g., the Global Financial Crisis

of 2008).

Thank you, I have replaced "the 2008 crisis" with "the Global Financial Crisis of 2008" to be more specific.

- Page 12: "stems from the wide variety of approaches" – instead of 'stems in'.

  Thank you, it has been corrected.

- When introducing technical terms and their abbreviations, all words should be capitalised (e.g., Quality Adjusted Life Years, Value of Statistical Life, Gross Domestic Product).

  Thank you, all the technical terms have been capitalised.

Chapter 2

This is the first substantive chapter of the thesis and a paper based on this chapter has already been published in the *European Journal of Health Economics*.

The chapter calculates the social costs of obesity in the Czech Republic and is careful and detailed in its methods. The chapter is also well written and well presented. The results should be of direct interest to policymakers/health care funders and highlight the high costs that obesity, as a disease, imposes.

Like Chapter 1, Chapter 2 is thorough, transparent, and competently executed. It is well placed within the existing literature and explicit about own data sources, methods and results.

Like in Chapter 1, I would appreciate an additional step from *what* is being done to *why* it is being done. Where the thesis deviates from some of the previous studies (as it necessarily will and should), it would be good to explain or justify this. Are the deviations due to a principled stance such as methodological superiority or due to practical considerations such as data availability? This comment pertains in particular to the definition of obesity. Why did the author(s) choose to use a binary classification (obesity: 0/1) when many previous studies focus on three obesity classes (I–III) or even individual BMI units? To be clear, I am satisfied with the author(s)' choice but I would like to see it more explicitly acknowledged and motivated, even if just briefly.

Thank you for this comment. I have updated the data description part, specifically the one where I talk about data sources for the prevalence of obesity, in the following way to address this issue:
Prevalence of obesity in the Czech Republic is taken from the NCD Risk Factor Collaboration (NCD-RisC) study with the most recent data being from 2016. This study provides the prevalence of obesity in 200 countries based on data measured by physicians. The data are stratified into 5-year age groups (see Figure 1.3) enabling more precise cost calculations. The age-standardised prevalence of obesity in population 20 years and older is 27.3% for men and 26.5% for women (Abarca-GÃłmez et al., 2017). For this study, obesity is defined as BMI≥30, without distinguishing between obesity classes (I-III). This decision is driven by two main factors. First, the primary aim is to estimate the overall burden of obesity in the Czech Republic rather than the differential impact of obesity severity. Second, the relative risk (RR) estimates used in the calculations correspond to obesity as BMI≥30, and disaggregated RR data for different obesity classes are not available. Given these data constraints, a binary classification (obese/non-obese) provides the most reliable and consistent approach for our analysis.

Minor (roughly in the order of importance):

- Box 1 is identical to Appendix A.2. Please keep one or the other.

  Thank you for noticing this, it has been deleted from the Appendix.

- Section 2.2 which provides a background on obesity uses both international and Czech data sources. I think it would be good to remind the reader that even international sources are used here to provide estimates specific to the Czech Republic (or at least I believe that to be the case). For example, the title to Figure 2.1 could explicitly say "Evolution of obesity in adults (18+) in the Czech Republic".

  Thank you for bringing this up. The title of Figure 2.1 has been changed as suggested, and I have also slightly updated the paragraph describing the data sources:

  The data on prevalence of obesity in the Czech Republic are available from various sources, including STEM/MARK, European Health Examination Survey (EHES), European Health Interview Survey (EHIS), MONICA, NCD-RisC study and the Global Health Observatory. These datasets exhibit some variability due to differences in methodology,

sampled populations, and age groups considered. While some of these sources are international, they provide country specific estimates for the Czech Republic. Regarding the evolution of obesity in adults, data from the Global Health Observatory (World Health Organization 2024) indicate a steady increase in obesity rates among adults aged 18+, with men consistently showing a higher prevalence than women since 2002 (see Figure 1.1).

- For readers who are not familiar with the measurement of obesity in children, it may be confusing how a relative measure (based on percentiles) may be used to study changes in levels over time. For example, how can more than 3% of children be above the 97th percentile and hence considered 'obese' (Figure 2.2)? It would be good to explicitly explain how changes in levels over time are based on comparisons to a reference year and the weight/height that defined the 97th percentile then.

  Thank you for this insightful comment. I recognize that the use of a relative measure like percentiles may not be immediately intuitive for all readers. To clarify, the percentiles used to define obesity (e.g., the 97th percentile) are based on a reference population, typically derived from historical growth charts. This means that obesity classification is relative to the weight and height distribution of children in the reference year rather than a fixed, absolute threshold. The paragraph about measurement of obesity among children has been changed in the following way:
  Although the costs of obesity among children are not included in present study, the trends in the prevalence of obesity in children deserve a note as the prevalence has been rising since the 90s (see Figure 1.2). In children, obesity is not assessed based on BMI, but based on percentile graphs (see Table 1.2). These charts are derived from nationwide surveys that measure children's height and weight within a given year. In the Czech Republic, the reference dataset comes from the 5th Nationwide Anthropological Survey of Children and Youth conducted in 1991. To track changes in obesity prevalence over time, the current distribution of children's height and weight is compared to the reference percentiles. Importantly, the 97th percentile is not a fixed threshold but is defined based on the reference population. If more than 3% of children today exceed the historical 97th percentile cutoff, it indicates that the overall weight distribution has shifted upward, meaning children today are generally heavier compared to the reference group. Looking at Figure 1.2, we can see that in 1991, 3% of children were classified as

obese, whereas by 2021, this figure had risen to 16.4%. This sharp increase highlights the substantial upward shift in children's weight distribution over the past three decades.

- Page 32: "Only one study focuses on five European countries" – please reference that study in text.

  Thank you for pointing this out, the reference (Gupta *et al.*, 2015) has been added.

- Page 27: USA and United States are used interchangeably in a single sentence – please use one term consistently.

  Thank you for this comment, it has been changed to "USA" to be consistent.

- Page 34: "We mainly use EHES data and complete them with the EHIS data" – should this be 'complement'?

  Thank you for this comment, this should indeed be "complement" and it has been corrected in the text.

- Many tables in Chapter 2 have the same Note: "values are in millions EUR". A more tailored Note may be in order in Tables 2.8 (which also includes days lost - in days) and 2.11 (which already specifies the units of measurement in column headings).

  Thank you for this comment, the notes have been updated.

- Box 1/Appendix A.2.: 'our estimate' (not ours) & 'cost for a different set of diseases'

  Thank you, these typos have been corrected.

Chapter 3

Chapter 3 calculates the social costs of smoking in the Czech Republic and, in many ways, it is conceptually and analytically similar to Chapter 2. One extension is that past smoking is analysed in addition to current smoking (while obesity was assumed to affect costs only contemporaneously). Another noteworthy extension is the use of the friction cost approach, as an alternative to cost-of-illness, when quantifying indirect costs.

Moreover, a separate study of the costs of smoking is obviously needed for policy/health care planning purposes. A paper based on Chapter 3 has been published in *Applied Health Economics and Health Policy*.
Like with the two previous chapters, I would like to see an explanation / justification of the author's choices. In Chapter 3, this primarily concerns the exclusion of second-hand smoke (SHS). In the very first paragraph, the author draws attention to the importance of SHS by writing: "Globally, tobacco kills more than 8 million people each year [...] Furthermore, more than 1 million of these deaths are estimated to be caused by secondhand smoke exposure" (p.50) Then, on the following page, the author cites previous studies which analyse SHS. Given this motivation, I would expect an explicit statement, early on, on how Chapter 3 tackles this issue and why. Instead, I believe the author only addresses this head-on in the concluding Discussion, where the reader learns that SHS costs were excluded due to data limitations (p.77) While this is an understandable justification in the form of a practical constraint, it would be good to see it much sooner – and then perhaps reiterated under Discussion.

Thank you for bringing up this issue. I agree that this should be stated right at the beginning of the chapter. I have updated the Introduction, now the third paragraph explains the exclusion of costs due to SHS exposure:
This analysis adopts a prevalence-based cost-of-illness approach, which views the costs of smoking as the sum of direct and indirect costs. This study is novel in being the most comprehensive, up-to-date, country-level cost-of-illness study, encompassing a broad range of direct and indirect cost components. However, it is important to note that this analysis does not quantify the costs of Secondhand Smoke (SHS) exposure due to data limitations. Specifically, while the health risks and mortality burden of SHS are well-documented, reliable national-level data on the number of individuals affected by SHS exposure in the Czech Re public are not available. As a result, this study focuses solely on the costs directly attributable to smokers themselves. Moreover, this analysis does not include intangible costs such as pain, suffering, and reduced quality of life in the core estimates. While these burdens represent an important part of the overall impact of smoking, they are excluded from the monetary estimates in this chapter in order to ensure methodological consistency and comparability with the majority of cost-of-illness studies. This focus on tangible direct and indirect costs is in line with standard practice in the literature. The analysis highlights the substantial burden of smoking in the Czech Republic, despite a recent decline in prevalence rates (NIPH 2022b).

Additionally, the first paragraph of Discussion has been updated to make it clear:
This study aimed to quantify the economic burden of smoking in the Czech Republic in 2019, which amounts to 2119.3 mil EUR, corresponding to 0.94% of GDP. These costs are calculated using a prevalence-based cost-of-illness framework, applying the attributable risk method for direct costs and the human capital approach for indirect costs. We do not include intangible costs in the analysis, or the costs of SHS exposure. While SHS exposure is a well-documented public health concern, national-level data on the number of individuals affected by SHS exposure in the Czech Republic are not available. This study focuses solely on the costs directly attributable to smokers themselves. These exclusions imply that the results represent a lower bound of the true social burden of smoking, as only the first two components of the Health Production Function, namely medical care and productivity losses, are included in the analysis. Comparability across cost-of-illness studies is limited due to differing methodologies and cost components. To illustrate this variation, we apply the friction cost approach (FCA) as an alternative method for valuing productivity losses. The resulting costs using this approach are much lower and are equal to 63.4 mil EUR.

Minor/typos:

- Page 68: 'cerebrovascular disease' (not 'serebrovascular')
- Page 77: "We thus perform a thorough sensitivity analysis" (capital W)

Thank you, the typos have been corrected.

Chapter 4

Chapter 4 presents a macroeconomic, time-series analysis of the revenue side of public health insurance in the Czech Republic. Specifically, the author sets out to investigate how health insurance revenue varies with the business cycle. The main finding is that revenue is pro- cyclical, and that the resulting business cycle fluctuations are quite large. In addition to being of interest on its own (as also evidenced by its recent publication in Health Economics Review), Chapter 4 adds to the thesis by demonstrating the author's breadth of research applications and analytical skills. The case studies of Estonia, Lithuania and Greece are also interesting and demonstrate how the author is aware of the importance of institutional features.

My only substantive concern is that the categories of health insurance revenue are currently not well explained. In particular, where they are first introduced, the author writes: "The health insurance funds in the Czech Republic collect revenues from four sources: (i) employers and employees [...], (ii) economically inactive individuals who are defined by law [...], (iii) self-employed individuals [...] and (iv) individuals without taxable income". (p.81) Later on, the terms 'state contributions' and 'state-insured individuals' get introduced but it is not clear whether these terms refer just to category (ii) or also category (iv). Then, unemployment is mentioned but not tied with a specific revenue category. Does it fall under (iv)? And does category (ii) primarily include children and the elderly? This all matters for interpreting the findings.

Thank you for this important comment. It is true that for a reader unfamiliar with the Czech healthcare system, this is confusing. After the introduction, a new section has been created (Section 3.2) which reviews the most important aspects of the Czech healthcare system. The list of categories now contains the information about who belongs to the category of economically inactive individuals in a footnote (children, students, women or men on parental leave, pensioners, unemployed individuals, people living below the poverty line, prisoners and asylum seekers). So to answer your questions, unemployment falls into category (ii), and children and elderly also belong to category (ii).

For example, the author summarises her results as follows: "The results support our expectation that during economic downturns, employer-employee contributions decline. This occurs for two reasons: (i) wages decrease during economic downturns and (ii) people lose jobs and thus become eligible for the state coverage." (p.98) Is 'state coverage' referring to revenue category (ii), (iv) or both? Presumably (iv) as that is where I believe unemployed individuals fall. However, the author excludes category (iv) (and category (iii)) from her analysis. Adding to confusion, while the quote above refers to those 'eligible for state coverage' and presumably category (iv), in Figure 4.1 'state insured' only refers to category (ii). The author should explain the revenue categories more transparently – who funds each category? on behalf of whom? – and use specific terms more consistently – terms like 'state contributions', 'state-insured individuals' and 'state coverage' should always clearly refer to the same concept.

Thank you for this very important comment. I did not realize that this is in fact confus-

ing for those who are unaware of how the funding of Czech SHI works. To answer your specific questions: "state coverage" refers solely to group (ii) of the economically inactive individuals (including the unemployed, students, seniors etc.). Category (iv) is excluded from the analysis, because it makes only about 1% of the SHI revenues. "Eligible for state coverage" refers again to group (ii) of economically inactive individuals, on whose behalf the state pays the contributions. I hope that the section 3.2, where I describe the Czech healthcare system, will help readers to understand this.
Additionally, the text you are referring to has been rewritten as:
The results support our expectation that during economic downturns, employer-employee contributions decline. This occurs for two reasons: (i) wages decrease during economic downturns and (ii) people lose jobs and thus fall in the category of state-insured, where the state pays the contributions on their behalf.
The category (iv) captures individuals without taxable income, which does not include the unemployed. An example of individuals without taxable income are people who do not have any income, but are not registered as unemployed, or stay-at-home women who are not caring for kids, or students who do not immediately start working after finishing their studies. This is the smallest group of the overall SHI income, whose contributions make only about 1% of the SHI revenues.

Minor/typos:

- Please be careful not to use double-negative in English (e.g., 'has not yet been quantified neither in the SHI [...] nor in the general taxation [...] scheme" (p.79) – should be 'either' and 'or'; "the signs of the effects do not clearly suggest neither pro-cyclicality, nor counter- cyclicality of state contributions" (p.94 & a variant on p.100) – should again be 'either' and 'or').

  Thank you very much for pointing out these mistakes, I have corrected them in the manuscript.

Chapter 5
Chapter 5 succinctly concludes the thesis by tying all the substantive chapters together one more time. It is an appropriate ending and a fair, brief summary.

Overall assessment

Overall, the thesis has substantive original contributions, is based on relevant references, and would be defendable at my home institution. All three main chapters have already been published in respectable journals and the author should be commended for her work. While I recommend that the author makes some revisions prior to the defense (so (b) the thesis can be defended after revision indicated in my comments), I do not consider any of my comments to be major and hence am not expecting any substantial changes. In my opinion, the thesis will be ready for defense after relatively small amendments.

E.4 Opponent's Report on Dissertation Thesis

Olena Stavrunova Ph.D., University of Technology Sydney

The thesis presents significant contributions structured around two key themes with important policy implications. First, it provides accurate social cost estimates for obesity and smoking – either pioneering such analysis for the Czech Republic or substantially expanding upon limited existing literature. Second, it offers the first Czech investigation into the procyclicality of statutory health insurance revenues. Both themes are critically important for evidence-based policymaking, as they provide economic foundations for healthcare planning, resource allocation, and fiscal preparedness in the health sector. This research addresses a critical gap in Czech health economics literature and will substantially inform national health policy while providing valuable data for international comparative analysis.

All three chapters have already secured publication in prestigious journals. In my assessment, this dissertation would meet the standards for the defence at my institution, the University of Technology Sydney.

I recommend the thesis proceed to defence without requiring substantial revisions. However, I suggest minor improvements–primarily expanding discussion on points identified below– would enhance the final document. I would appreciate the candidate addressing some of these items during the defence and incorporating relevant changes into the final version, time permitting.

Chapter 1. Introduction

The dissertation offers a clear and compelling explanation for why these topics need study. I appreciate how the author presents different ways to calculate illness costs and then explains and justifies their chosen method. This makes the work much easier for readers to understand and follow.

Chapter 2. Social Costs of Obesity in the Czech Republic.

This chapter represents a thorough and well-executed estimation of the social costs of obesity in the Czech Republic. It presents a comprehensive literature review, an appropriately selected methodology, a clear analytical framework, and a thorough sensitivity analysis that strengthens the reliability of the findings. The comparative discussion of

the thesis findings with those of the OECD study is well-executed, providing a convincing explanation for the differences in the estimates. The discussion of data limitations is also appropriately thorough.

1. Literature review

While your discussion of obesity trends among children and adults in the section "Obesity" is thorough, I recommend restructuring for better coherence:

1. The first page of the literature review contains content about obesity trends among adults that appears thematically similar to the content in the preceding section (first paragraph and the first half of the second paragraph). For improved structure, consider moving all adult obesity trend discussions to the "Obesity" section.

   Thank you for pointing this out. I have moved the discussion about adult obesity into the Obesity section for better structure. Similarly, the part of the literature review that addressed studies conducted for the Czech Republic has also been moved to section 1.3.3 which is specifically dedicated to it.

2. Please explain briefly the methodology used to calculate the relative risks of obesity, e.g., Guh *et al.* (2009) and Dobbins *et al.* (2013). It would be great if you did the same for the relative risks of smoking in Chapter 3 by explaining the methodology in Hannan *et al.* (2009) and other papers listed in Table 3.3. In particular, I wonder whether other lifestyle factors–such as diet quality and physical activity–are accounted for in these methodologies, given their potential independent influence on disease outcomes and correlation with obesity and smoking. Please briefly discuss any limitations of this methodology (if any) to help readers better assess the robustness of your estimates.

   Thank you for this valuable comment. I fully agree that it is important to provide additional context on the methodology behind the relative risks used in the analysis, as well as their potential limitations. In response, I have expanded the methodological discussion in the revised manuscript to clarify how these relative risks (RRs) were derived and how confounding factors, such as physical activity and diet, may affect the interpretation of the results:

   Relative risks used in this study are based on two high-quality meta-analyses: Guh et

al. (2009) and Dobbins et al. (2013). Guh et al. (2009) conducted a systematic review of 89 epidemiological studies published between 1994 and 2006, examining the association between obesity (BMI$\geq$30) and 18 comorbidities. Only prospective cohort studies were included, with a majority conducted in the US (55%) and Europe (40%). The meta-analysis used random-effects models based on maximum likelihood estimation and adjusted for key demographic variables such as age, sex, and ethnicity. However, the study did not adjust for physical inactivity–an important risk factor correlated with obesity and independently associated with some comorbidities–due to inconsistent reporting across studies. This omission may introduce omitted variable bias, potentially leading to an overestimation of the impact of obesity. Dobbins et al. (2013) performed a systematic review and meta-analysis of 57 studies (43 cohort and 14 case-control) published between 1985 and 2011 to assess the association between obesity and 13 types of cancer. Most included studies originated from the US, Sweden, Norway, and Japan. The authors used the DerSimonian and Laird random-effects model to pool estimates and adjusted for various confounders, although behavioral factors were not consistently specified. Despite some limitations–especially regarding adjustment for lifestyle variables such as diet and physical activity–these meta-analyses provide the most comprehensive and systematically derived relative risks currently available. The use of such pooled estimates allows for consistent application across diseases and enhances the comparability of results in cost-of-illness analyses. However, potential residual confounding should be acknowledged when interpreting the magnitude of risk.

And similarly, in Chapter 3, the methods section contains more detailed information about how these relative risks (RRs) were derived:
The RRs for adult mortality from smoking-related diseases used in this study are summarized in Table 2.1. These estimates are primarily based on the Cancer Prevention Study II (CPS-II) and are taken from the 2014 US Surgeon General's Report (US Department of Health and Human Services 2014). The CPS-II cohort forms the empirical basis for most relative risk estimates used in Smoking-Attributable Mortality, Morbidity, and Economic Costs (SAMMEC) calculations. The models adjust for age, sex, race, and education, but do not fully control for behavioral confounders such as alcohol use or diet. However, Thun et al. (2000) have shown that adding these factors produces only minor adjustments to the risk estimates, suggesting limited bias due to omitted variables. In addition to CPS-II data, relative risks for specific conditions are drawn

from more recent and methodologically rigorous studies. For instance, Hannan et al. (2009) derive RRs for colorectal cancer from CPS-II by employing Cox proportional hazards models with time-varying covariates and adjusting for thirteen confounding factors, including BMI, diet, alcohol, physical activity, screening history, and hormone therapy. Ezzati et al. (2005) estimate smoking attributable cancer mortality using CPS-II data as well, but include broader socioeconomic and dietary controls, offering robust site-specific RRs for global and regional cancer clusters. For ovarian cancer, Jordan et al. (2006) conduct a systematic review and meta-analysis using random-effects models and control for reproductive factors like parity and oral contraceptive use, which are important confounders in gynecological cancers. These relative risks are used to compute the smoking-attributable fractions (Smoking-attributable Fractions (SAFs)) for each disease (see Section 2.4). Due to the lack of morbidity-specific relative risks in the Czech context, mortality based RRs are used as proxies for morbidity risks, following a common practice in cost-of-illness studies3 (Anh et al. 2016; Sung et al. 2014; Cher et al. 2017; Boachie et al. 2021). This approach assumes that the diseases associated with higher mortality among smokers, such as cancer, COPD, and cardiovascular disease, also impose a proportionally higher burden in terms of morbidity and healthcare costs. While this introduces a simplification, it provides a feasible way to estimate smoking-attributable morbidity in the absence of more detailed morbidity risk data.

2. Methodological Concerns

In section 2.4, extrapolating insured population costs to the uninsured population raises methodological concerns. The uninsured population likely exhibits distinct cost profiles attributable to differences in health status, healthcare access patterns, and socioeconomic factors. Please discuss whether this extrapolation will likely systematically bias your results due to the demographic and behavioural differences between the two groups.

Thank you for highlighting this important issue. I realize that this section does not clearly convey that nearly 100% of the Czech population is insured with a health insurance fund. This is explained in more detail in the final chapter, where Section 3.2 provides an overview of the Czech healthcare system. To clarify this point, I have expanded the footnote for better reader understanding: The extrapolation coefficient is 1.79, as 5.95 million people were insured with the GHIF in 2018, while the total Czech population was 10.65 million. In the Czech Republic, all permanent residents are required to be insured with one of the seven

health insurance funds, ensuring nearly 100% coverage. GHIF is the largest of these funds, covering the majority of the Czech population.

3. Additional Considerations

I believe two areas need further clarification:

1. Obesity treatment costs are excluded because they're not covered by insurance, but these represent actual economic costs born by individuals and should presumably be included among the social cost of obesity. Consider including these costs or providing estimated ranges to present a more complete economic picture.

   The reviewer probably refers to the pharmacotherapy costs used in the cure of obesity (these are not covered by insurance). While I would have liked to include these costs in the study, there are currently no available data for such an estimate. I made extensive efforts to obtain them, reaching out to the State Institute for Drug Control (which only has data on insurance-covered drugs), the Czech Statistical Office (which provides aggregate data on household expenditures for prescription and over-the-counter drugs but not by ATC groups), and the Ministry of Industry and Trade, which also confirmed they do not have such data. Lastly, I contacted the Ministry of Health, which also responded that they do not have such data; they only have information on pharmaceuticals covered by health insurance.

   A footnote has been added to Table 1.7:
   Pharmaceuticals used in the treatment of obesity are not covered by health insurance. An attempt was made to estimate these costs by contacting the State Institute for Drug Control, the Czech Statistical Office, the Ministry of Industry and Trade, and the Ministry of Health. However, none of these institutions collect data on pharmaceuticals that are not reimbursed by health insurance in the Czech Republic.

   Otherwise, the healthcare costs of treating obesity are included in the healthcare utilization costs – these are the costs where the main cause of receiving treatment was diagnosis obesity.

2. Regarding "days of terminated cases of incapacity for work for obesity-related comorbidities," please clarify if this metric captures all missed workdays or only certain categories/types of enterprises. Explain the specific criteria for missed work to be

recorded in this dataset. If this metric only captures part of absenteeism costs, please discuss how that limitation could affect your results.

Thank you for raising this important question, which I had not considered before. The dataset includes all instances of work incapacity recorded through a standardized form issued by the Czech Social Security Administration. In practice, when a doctor determines that a patient is unable to work due to being sick, they complete this form and assign an ICD-10 code indicating the reason for incapacity. In 2018, individuals on sick leave received 60% of their average wage starting from the fourth day of illness. Importantly, only those who contribute to the sickness benefit system (primarily employees and some self-employed individuals) are eligible for sick leave. In the Czech Republic, nearly half of the population pays sickness insurance (in 2018, it was 4 732 700 people according to the Czech Statistical Office, while there were 5 147 thousands people employed according to Eurostat, so 92% of employed people pay the sickness benefits). Those who do not, such as the unemployed, parents on parental leave, prisoners, and certain self-employed individuals, are ineligible for sick leave and thus are not captured in the dataset. However, since these individuals are not engaged in paid employment, their illness does not result in measurable productivity losses from an economic perspective.
The following note has been added to the limitations section in the discussion:
One important limitation of the study relates to the measurement of absenteeism due to obesity-related illnesses. The analysis uses data on days of terminated cases of incapacity for work," which are recorded by the Czech Social Security Administration. These data capture instances where a physician officially declares a person temporarily unfit for work, assigns an ICD-10 diagnosis code, and submits a standardized form. However, this dataset only includes individuals eligible for sickness benefits, primarily employees and some self-employed individuals who pay into the sickness insurance system. In 2018, approximately 92% of employed individuals contributed to sickness insurance and were thus eligible for sick leave. Conversely, groups such as the unemployed, parents on parental leave, and some self-employed individuals are not eligible for sick leave and are not recorded in this dataset. While this may seem like a potential source of underestimation, these individuals are not engaged in paid employment and therefore their illness does not generate productivity losses in the traditional economic sense. Still, the restriction of the data to only those paying sickness insurance means that a small portion of potential productivity losses, especially among informal or unpaid work, might

not be captured, and this should be considered when interpreting the results.

And similar note for the chapter 2:
Another important limitation of the study concerns the measurement of absenteeism due to smoking-related illnesses. The analysis relies on data from the Czech Social Security Administration, which record days of work incapacity certified by a physician and linked to a smoking-related diagnosis. However, these records cover only individuals eligible for sickness insurance, mainly employees and some self-employed persons. Groups such as the unemployed, those on parental leave, and self-employed individuals not contributing to sickness insurance are excluded. While these individuals are typically not in paid employment and thus do not generate productivity losses in the conventional economic sense, some informal or unpaid work losses may remain unaccounted for and should be acknowledged when interpreting the results.

Overall, these are minor refinements to what is already a very strong chapter.

Chapter 3. Social costs of smoking in the Czech Republic.
This chapter estimates the social costs of smoking in the Czech Republic. The literature review is comprehensive, the methodology is well-chosen, and the analytical framework is clear. The chapter includes extensive sensitivity analyses, in-depth discussion of differences with other Czech studies, and explanations for these discrepancies. I suggest a few minor improvements to enhance reader comprehension and strengthen the overall cohesiveness of the thesis.

1. Clarification of Similarities and Differences in Methodology between Chapters 2 and 3
The methodological approaches in Chapters 2 and 3 appear similar, though the thesis does not explicitly present them as such. To aid comprehension, it would be helpful if the introduction of Chapter 3 included a few paragraphs specifically explaining these similarities and differences. This could address what is consistent (e.g., data sources, computational techniques) and what differs (e.g., distinct relative risks from various international studies, the use of different prevalence or healthcare utilization datasets). Also, please clarify why the two chapters used different data sets to measure prevalence and healthcare costs.

Thank you for this helpful suggestion. In response, I have added a paragraph to the intro-

duction of Chapter 2 that outlines the methodological consistencies and differences between Chapters 1 and 2 (the chapter numbering has been changed in response to reviewer one's suggestion). While both chapters are based on the Cost-of-Illness methodology and share several computational elements, they differ in terms of data sources and the structure of the sensitivity analysis, which is now clearly explained. These differences primarily stem from data availability and the nature of the risk factor analysed in each chapter. The updated introduction also clarifies why different datasets were used to estimate prevalence and healthcare utilization costs. I believe this addition will help the reader better understand the methodological logic and evolution across the dissertation. The following paragraphs have been added to the introduction of Chapter 2:

This chapter builds upon the methodological foundation established in Chapter 1, as both analyses adopt the COI framework. In both cases, direct costs are estimated using the top-down approach, while indirect costs are computed using the HCA. The core computational procedures are thus consistent across the two chapters. However, important differences also arise due to data availability and the nature of the risk factors: smoking here versus obesity in Chapter 1. The chapters differ in the data sources used for estimating health care utilization and prevalence. Chapter 1 relies on aggregated data from the General Health Insurance Fund (GHIF), which are not disaggregated by gender or age. Due to access constraints, this chapter uses a different source, specifically from the Institute of Health Information and Statistics (IHIS), which offer more granular insights by age and gender. Similarly, smoking prevalence is based on the 2019 wave of the European Health Interview Survey (EHIS), chosen for its national representativeness and age stratification, which is crucial for precise cost estimates. Other data sources, such as those for wages, amount of paid and unpaid work, premature mortality, life expectancy, and retirement age, remain consistent with Chapter 1. Another notable difference lies in the sensitivity analysis: Chapter 2 also applies the FCA to assess the robustness of indirect cost estimates, whereas Chapter 1 does not. This difference is due to the timing of the research. At the time Chapter 2 was written, the author had become familiar with both the methodology and the required data for applying FCA, whereas this was not the case during the preparation of Chapter 1. Additionally, the FCA was not widely applied in COI studies examining the economic burden of obesity, but it has been applied in sensitivity analysis of some studies estimating the economic burden of smoking.

2. Motivating Friction Cost Approach

Chapter 3 applies the friction cost approach to smoking. However, Chapter 2 does not

apply it to obesity. Please clarify the rationale behind this choice. If the intention was to highlight specific aspects of smoking-related costs, explain how these differ from obesity-related costs and why the friction cost approach was deemed suitable only for smoking.

Thank you for this comment. The decision to apply the friction cost approach (FCA) in Chapter 2 but not in Chapter 1 (the numbering of chapters has been changed) was primarily driven by practical and methodological considerations. First, Chapter 1 was completed and submitted for publication in a peer-reviewed journal prior to the development of Chapter 2. At the time of writing Chapter 1, I was not yet fully familiar with the FCA methodology, and consequently, I did not request the necessary data for its implementation. Second, although both smoking and obesity are associated with similar types of chronic diseases, such as cardiovascular conditions, respiratory illnesses, and cancers, the literature on Cost-of-Illness (COI) studies has more commonly applied FCA in the context of smoking than obesity. This precedent provided a clearer framework and empirical basis for applying FCA in the smoking analysis.
It is also worth noting that the decision to apply FCA in Chapter 2 serves primarily as a robustness check for the indirect cost estimates obtained using the HCA. The inclusion of FCA reflects the methodological evolution of the dissertation, which spans multiple years. By the time Chapter 2 was written, I had become more familiar with both the conceptual framework of FCA and the data requirements for its application.
To enhance clarity, a short note has been added to the Introduction of Chapter 2:
Another notable difference lies in the sensitivity analysis: Chapter 2 also applies the FCA to assess the robustness of indirect cost estimates, whereas Chapter 1 does not. This difference is due to the timing of the research. At the time Chapter 2 was written, the author had become familiar with both the methodology and the required data for applying FCA, whereas this was not the case during the preparation of Chapter 1. Additionally, the FCA was not widely applied in Cost-of-Illness (COI) studies examining the social costs of obesity, but it has been applied in sensitivity analysis of some studies estimating the economic burden of smoking.

3. Improving Discussion of Caregiving Costs

Chapter 3 mentions the exclusion of caregiving costs as a limitation, but there is no similar mention in Chapter 2. If caregiving costs are similarly relevant and similarly excluded in Chapter 2, please discuss this. Making these discussions consistent between the two such

similar chapters (or explicitly justifying differences) will strengthen the thesis's coherence.

Thank you for this thoughtful comment. You are absolutely right, caregiving costs are a relevant component of the broader societal burden for both smoking and obesity. In Chapter 1, these costs were not included in the baseline estimates, just like in Chapter 2. This omission was primarily due to the lack of reliable data on informal caregiving in the Czech Republic that would be specific to individuals with obesity-related conditions.
To ensure consistency and enhance the coherence of the thesis, I have revised the limitations section in Chapter 2 to explicitly acknowledge the exclusion of caregiving costs and to clarify that this exclusion may lead to underestimation of the total burden. I also note that these types of costs are often difficult to capture but can be substantial, particularly for chronic, disabling conditions. Including this parallel discussion helps to better align the two chapters and emphasize that both estimates should be interpreted as conservative, lower-bound figures.
The following paragraph has been added to limitations in Discussion section:
Finally, this study does not include the costs of informal caregivers or relatives related to obesity and its associated comorbidities. These costs can be substantial, especially for individuals with chronic or disabling conditions that require ongoing assistance with daily activities. However, reliable data on the extent and value of caregiving specific to obesity-related diseases are not available in the Czech Republic. The absence of such data prevents the inclusion of caregiving costs in the analysis, potentially leading to an underestimation of the total societal burden. This limitation is consistent with most cost-of-illness studies, which often omit caregiving costs due to the difficulty in measuring unpaid care and the lack of standardized valuation methods. Nonetheless, it is important to recognize that caregiving represents a real economic and social cost, and its exclusion should be taken into account when interpreting the overall findings.

4. Extending Policy Implications

Although it's clear that the costs of obesity and smoking identified are substantial, please elaborate on how these findings might inform policy decisions in the Czech Republic. How do your estimates add to existing knowledge in a way that concretely aids policymaking? Additionally, consider discussing whether welfare (as opposed to costs alone) could provide a more holistic basis for guiding policy.

Thank you for this insightful comment. The results presented in this dissertation offer impor-

tant policy-relevant evidence by quantifying the economic burden of obesity and smoking in the Czech Republic using a consistent and transparent methodology. These estimates serve several concrete policy functions:

- Priority-setting: The findings help identify obesity and smoking as major contributors to the Czech Republic's economic burden from non-communicable diseases, with combined social costs amounting to a significant share of GDP. This quantification enables policymakers to prioritize prevention and mitigation strategies in national health policy and budget planning.
- Resource allocation and program design: By decomposing total costs into direct (medical) and indirect (productivity-related) components, the results offer insight into the main cost drivers. For example, the large share of indirect costs suggests that interventions targeting working-age populations (e.g., smoking cessation in the workplace, healthy lifestyle promotion) could yield substantial economic returns.
- Cost-containment and prevention strategy: These estimates help inform targeted public health measures, such as taxation, regulation of unhealthy products (e.g., tobacco, sugary beverages), or subsidized lifestyle interventions. Policymakers can also use the cost composition to evaluate whether investment in prevention might reduce long-term healthcare and productivity losses.
- Czech-specific evidence: Until now, comprehensive cost-of-illness (COI) studies on these topics have been lacking for the Czech Republic. Existing estimates were either outdated, incomplete, or methodologically inconsistent. This study addresses that gap and provides a Czech-specific, comparable, and replicable estimate of the social costs of two major risk factors, which can inform domestic cost-effectiveness or budget impact analyses of proposed interventions.

Regarding the second part of the comment: I agree that from a normative policy perspective, welfare measures such as willingness-to-pay (WTP) or quality-adjusted life years (QALYs) offer a more complete framework for evaluating the burden of disease. This dissertation complements that perspective in two ways:

1. Newly added Appendix D provides an indicative estimate of intangible costs using several approaches (e.g. VSL), capturing the welfare losses from pain, suffering, and premature mortality that are not reflected in productivity losses alone. These intangible costs are

shown to substantially exceed the direct and indirect costs combined, reinforcing the argument for stronger prevention policies.

2. In the revised version of the introduction, a clearer distinction is now made between the human capital approach and the welfare-economic framework. While this thesis focuses primarily on economic costs (i.e., forgone production and healthcare expenditure), it explicitly acknowledges that such estimates represent a lower-bound of the total societal burden and are best interpreted as complementary to broader welfare-based measures.

This has been added in the thesis conclusion:
The findings from the first two chapters contribute to policymaking in the Czech Republic by providing robust, localized evidence on the economic burden of obesity and smoking. By quantifying the direct medical costs and productivity losses associated with these risk factors, the analysis offers a data-driven foundation for evaluating public health interventions such as taxation, behavioral prevention programs, and resource allocation. Importantly, the estimates are broken down by cost category (e.g., absenteeism, presenteeism, premature mortality), helping to identify high-impact areas for targeted policy response.
These results also update and expand the existing evidence base for the Czech Republic, using transparent and reproducible methods that enhance comparability with international studies. While global literature confirms the high economic costs of obesity and smoking, localized cost estimates are essential for adapting policy to national institutions, labor market conditions, and healthcare system design. As such, the findings can inform priority-setting, budget planning, and economic evaluations of preventive health policies. It is important to emphasize that the COI framework used in this thesis reflects only part of the total burden. Specifically, the analysis captures the first two components of the Health Production Function: direct healthcare costs and indirect productivity losses. It excludes the disutility from illness, such as pain, suffering, psychological distress, and quality-of-life losses, which are central to welfare economics but typically omitted from COI studies due to methodological and data constraints. Accordingly, the reported results should be interpreted as conservative, lower-bound estimates. To provide a fuller picture, Appendix D complements the core analysis with illustrative estimates of intangible costs using welfare economic approaches such as the VSL, the VSLY, and QALY- or DALY-based valuations. These additional figures underscore that the full societal burden of smoking and obesity likely exceeds the costs presented in the main chapters.
Looking forward, future research could extend this work by integrating both cost and welfare-based approaches, enabling a more holistic evaluation of health risks and policy options. In

particular, welfare-based metrics can be instrumental for assessing trade-offs in public health decision-making, especially when comparing interventions with different impacts on mortality, morbidity, and quality of life.

Chapter 4. Business cycle sensitivity of Statutory Health Insurance: Evidence from the Czech Republic.

This chapter addresses an important topic by examining whether social insurance fund revenues are pro-cyclical or counter-cyclical. It is a well-motivated, well-executed and well-written piece of work. However, several points could be clarified to strengthen the analysis:

1. Choice of Model (Static vs. Dynamic)

It is not entirely clear which model–the static or the dynamic–should serve as the primary specification. Because the static model is nested within the dynamic model, and specification tests appear to favour a dynamic model with a second lag, please clarify in the thesis which specification ultimately provides the main results. Also, please explain how you determined the number of lags to include in the dynamic model. It would be good to include the results of these tests in the appendix.

Thank you for this helpful comment. I agree that clarification is needed regarding the preferred model specification.

First, I acknowledge that the equation in the chapter contained a typographical error. Specifically, the summation index in the dynamic model should have been $k = 1$, not $k = 0$, to exclude the contemporaneous term and ensure a proper lag structure. This correction is important, and I have amended the equation accordingly.

Second, regarding the lag selection: the dynamic models with different lags were compared using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) across the three dependent variables (total revenues, employer-employee contributions, and state contributions – the specific results are reported in Table C.1 in Appendix C). The AIC/BIC do not consistently favor the specific lags to be chosen for the model with total revenues as dependent variable (AIC prefers lag 2, BIC prefers lag 1), but the criteria are consistent to choose lag 2 of nominal GDP for employer-employee contributions and lag 1 for state contributions.

Regarding the model selection (static vs. dynamic), AIC and BIC were also used to compare the static model with the best dynamic model. For total revenues and state contributions,

both criteria slightly favor the dynamic model; for the employer-employee contributions, both criteria slightly favor the static model.
However, given the economic context (particularly the presence of behavioral and administrative delays in healthcare financing and insurance contributions), it is reasonable to expect that there may be lagged effects in the relationship. These dynamics are especially relevant in the context of social health insurance systems, where changes in macroeconomic variables may not immediately translate into contributions or public revenues. Therefore, despite the relatively small statistical differences in AIC/BIC, I treat the dynamic specification (with one lag) as the main model in the final version of the chapter. This choice is motivated by both theory and practical considerations. The summary of results has been changed accordingly:
The results support our expectation that during economic downturns, employer-employee contributions decline. This occurs primarily because (i) wages tend to fall during recessions and (ii) individuals lose jobs and shift into the category of state-insured, where contributions are paid on their behalf by the government. The pro-cyclical effect is significant in both the contemporaneous and lagged models for total revenues and employer-employee contributions. The effect persists over two quarters, likely due to institutional and contractual frictions, such as wage stickiness and delayed layoffs, that prevent immediate adjustment in labor markets. Given these dynamics, the preferred model specification is the dynamic model with one lag, which is slightly favored by AIC and BIC criteria for total revenues and state contributions. Although the static model performs marginally better for employer-employee contributions, the dynamic model is retained as the main specification. This choice is supported by the economic context, where administrative and behavioral delays in the social health insurance system imply that macroeconomic shocks may not translate into contribution flows immediately. The dynamic model thus better captures the real-world timing of the relationship between the business cycle and health insurance revenues.
A short note has also been added into conclusion of the chapter, and in the introduction.

2. Interpretation of the Lagged Dependent Variable

The negative and statistically significant coefficient on the lagged dependent variable should be discussed in detail. Please offer an economic interpretation and address its potential policy implications.

Thank you for this insightful comment. The negative and statistically significant coefficients on the lagged dependent variable in all three regressions suggest the presence of mean rever-

sion in the quarterly growth rates of health insurance revenues and their components. This implies that unusually high growth in one quarter tends to be followed by lower growth in the subsequent quarter, and vice versa. Economically, this pattern may reflect administrative smoothing mechanisms, such as adjustments in reporting, contribution collection schedules, or delayed recognition of changes in payroll and employment. Additionally, it may signal the presence of automatic stabilizers in the SHI system: for instance, temporary fluctuations in economic activity may be partially absorbed or offset in the following quarter due to fixed contribution bases, averaging mechanisms, or correction of estimation errors.
From a policy perspective, this mean-reverting dynamic highlights the importance of medium-term planning and reserve management. Policymakers should not overreact to quarterly spikes or drops in revenue growth, as these may partly reverse in the subsequent period. Instead, ensuring stable financing of health insurance funds may require instruments that account for these temporary dynamics, such as smoothing rules, reserve buffers, or longer-term fiscal outlooks.
The following note has been added in the results section:
A key finding across all three equations is the negative and significant coefficient on the lagged dependent variable, indicating mean reversion in quarterly growth rates of SHI revenues. This suggests that above-average growth in one quarter tends to be followed by below-average growth in the next, and vice versa. Such dynamics may be caused by administrative delays, payment timing, or cyclical corrections. From a policy perspective, this underlines the importance of not over-interpreting short-term fluctuations and ensuring that contribution systems have the capacity to absorb temporary volatility through stabilization mechanisms or reserves.

3. Lagged Business Cycle Indicators

For regressions using business cycle indicators other than output, it would help to specify which lags were employed and how those lag lengths were chosen.

Thank you for the comment. For regressions using business cycle indicators other than output (i.e., nominal GDP), the number of lags was selected using model selection criteria, specifically the Akaike Information Criterion (AIC). While both AIC and BIC were computed, the final decision was based on AIC, which is often preferred in smaller samples or when the objective is to minimize the risk of underfitting by allowing slightly more complex models. To ensure transparency, the results of the AIC/BIC tests are now included in Appendix C. The chosen lags correspond to the specifications that minimized AIC for each respective indicator.

4. Potential for Counterfactual Simulations

Finally, consider illustrating how the model could be used in counterfactual scenarios. For instance, under certain assumptions about expenditures, what does the model predict regarding the funding gap during typical or severe recessions? This would provide valuable insights into the practical policy applications of your findings.

Thank you for this valuable suggestion. I have incorporated a new section titled "Counterfactual scenario: a typical recession" directly into the main body of the chapter (see Section 3.4.5). In this section, I simulate the predicted impact of a moderate economic downturn, defined as a 3% contraction in GDP sustained over two quarters, on SHI revenues.
The simulation uses the coefficients from the lagged model, particularly the estimated elasticity of SHI revenues with respect to GDP. It demonstrates how the model can be applied to estimate the short-term funding gap that may arise during a recession. This addition helps translate the empirical findings into practical policy insights, as you suggested.

E.5 Comments received from Dr. Milan Ščasný, IES FSV UK

1. Link your empirical work to theory

The dissertation should introduce health production function (e.g., Grossman 1972; Cropper 1981; Harrington and Portney, 1987). I share my slides on HPF (although it is linked to pollution, it may be applied to smoking). Following the HPF, the marginal value of illness is a sum of i) marginal loss of earnings due to sickness, ii) medical treatment costs, iii) marginal cost of averting activities, and iv) disutility due to illness (pain, suffering, and other inconveniences) converted into dollars (dividing by MU of income), that is, w*dW/dS + (pM*dM/dS) + pA *dA/dS) + dU/dS / l The HPF defines clearly what is the total economic (social) cost of illness or illness burden. It also implies we can't call COI (the first and second component] as the cost of smoking since at least the last component is missing. This needs to be clarified and corrected everywhere, incl. Chapters 2 and 3.

Thank you for your suggestion regarding the inclusion of the Health Production Function (HPF) framework. In response, I have incorporated a dedicated theoretical section in the introduction of the thesis, summarizing the key contributions of Grossman (1972), Cropper (1981), and Harrington & Portney (1987). This section explicitly presents the HPF equation and its components–marginal loss of earnings, medical treatment costs, averting behavior, and disutility from illness–and clarifies their relevance to the economic valuation of health.
I have also revised Chapters 2 and 3 to clearly state that our cost-of-illness (COI) calculations capture only the first two components of the HPF: direct medical costs and productivity losses. The omission of averting behavior and disutility is now explicitly acknowledged in both chapters, and the resulting figures are consistently described as lower-bound estimates of the total social costs. An illustrative discussion and separate calculations of intangible costs have been added to Appendix D to further address these components. These changes aim to clarify the scope of our methodology and ensure consistency with the welfare-based interpretation of illness burden outlined in the HPF literature.

2. COI Approach

COI is based on human capital approach (Rice *et al.*, 1966); btw, the valuation of prema-

ture mortality based on human capital approach does not conform welfare economics (consensus has been agreed a long time ago). It should be described all items of COI (I think I was missing off-pocket medical expenditures, indirect costs of other family members etc.). On the other hand, the fourth component of the total costs (diswelfare) is not a part of COI, see USEPA COI Handbook 2002, OECD 2016 (Pearce, Murato); there is also a useful summary review by Prof. Alberini; see, `https://www.oecd.org/en/publications/measuring-the-economic-value-of-the-effects-of-chemicals-on-ecological-systems-and-human-health_9dc90f8d-en.html`. I would appreciate to discuss COI if prevalence (all patient given period) or incidence (all new cases in given period) is followed; when one or the other shall be used and what they indicate.

HCA and welfare economics:

I acknowledge that the Human Capital Approach, originally introduced by Rice *et al.* (1967), does not align with the principles of welfare economics, particularly in valuing premature mortality. This limitation is now explicitly acknowledged in the introduction. In line with your suggestion, the text clarifies that HCA-based estimates, while standard in COI studies, do not reflect individuals' full willingness to pay (WTP) to avoid premature death.

Scope of COI and missing cost items:

Thank you for the valuable comment. I agree that out-of-pocket payments and informal caregiving represent important cost components. Their exclusion is noted in the discussion of each chapter. These items were omitted due to data limitations, which is common in COI studies. Nonetheless, their absence is now clearly emphasized as a limitation that may lead to an underestimation of the total burden.

Disutility and its place outside COI:

I fully agree that the disutility of illness (pain, suffering, and reduced quality of life) is not part of the standard COI framework. As such, this component is not included in the baseline COI estimates, but it is now discussed both conceptually (in the theoretical section) and quantitatively (in Appendix D), using VSL, VSLY, DALY, and QALY approaches.

Prevalence vs. Incidence Approaches in COI Studies:

Thank you for this comment. The conceptual distinction between prevalence- and incidence-based COI approaches is already discussed in the Introduction (Section: Methodological background: valuing the burden of disease). This thesis adopts the prevalence-based approach in both chapters, as it is particularly well-suited for describing the overall societal burden of diseases such as obesity and smoking in a given year – a key objective of this research.

Unlike the incidence-based approach, which is ideal for evaluating long-term cost savings of specific prevention or intervention strategies, the prevalence-based framework offers a more policy-relevant snapshot of the current resource use and productivity losses. This makes it especially effective for highlighting the need for public health responses in areas where the burden may be underestimated.

3. Disutility

3.a dU/dS One should never ignore disutility since it contributes heavily to the total costs of illness; at least one should acknowledge a magnitude, or at least the order of magnitude compared to COI component at least for a few health end-points. It can't be said "the studies do not exist" (which is not true) or "the WTP method is questionable" (which is not true either, Note: friction cost and cost of absenteeism are also based on self-reported data in a survey, correct?

Thank you for this important comment. I fully agree that disutility represents a substantial component of the total burden of illness and should not be disregarded. While this study follows the conventional cost-of-illness (COI) framework, capturing only the first two components of the Health Production Function (direct and indirect costs), it now explicitly acknowledges the significance of intangible costs, both in the introduction and in a newly added Appendix D.

In the introduction, I reference studies that quantify intangible costs using willingness-to-pay (WTP) and QALY-based approaches, demonstrating that in many cases these costs can exceed the sum of direct and indirect components. I also cite the foundational work of Rice (1967), who emphasized both the relevance and the challenges of incorporating such welfare losses into COI analyses.

To provide a sense of scale, Appendix D presents illustrative estimates of intangible costs for both smoking and obesity. These are derived using the Value of a Statistical Life (VSL), Value of a Statistical Life Year (VSLY), DALYs, and QALYs. The resulting figures span a wide range, underscoring the sensitivity of outcomes to methodological choices and valuation assumptions.

Regarding the note on self-reported data: you are correct that some components of COI studies rely on self-reported information. In this thesis, presenteeism is the only component based on self-reported productivity loss. In contrast, absenteeism and Friction Cost Approach (FCA) calculations are based on administrative data and modeled assumptions, not survey

self-reports.

3.b. Premature mortality

Association with premature mortality in particular for smoking and obesity should not be ignored. Importance to discuss mortality increases if one use mortality rate is deriving the key parameter of COI (SAF).

Moreover, it is not true VSL studies are not existent; there have been several VSL studies conducted in the Czech Republic, including VSL for cancer, see Alberini & Scasny 2011; 2013; 2018, 2021, Alberini *et al.*, 2023.

Thank you for this important observation. I fully agree that the association between smoking, obesity, and premature mortality is essential and should be appropriately highlighted. In line with this, the baseline cost-of-illness computations in Chapters 2 and 3 include the costs of premature mortality as a major component of indirect costs. Furthermore, I have clarified in both the methodology and discussion sections that due to the lack of morbidity-specific relative risks (RRs) in the Czech Republic, mortality-based RRs were used as proxies to derive smoking-attributable fractions (SAFs), a common practice in COI studies (also endorsed by the WHO toolkit, see point 4 of this response letter).

Regarding the availability of VSL estimates, I fully acknowledge that several relevant studies have been conducted in the Czech Republic, including those by Alberini and Scasny (2011, 2013, 2018, 2021) and Alberini *et al.* (2023), and I appreciate the references. The statement in the thesis about the lack of data was specifically referring to the absence of country-specific estimates for QALYs lost due to smoking or obesity, which I considered necessary for fully incorporating intangible costs into the COI framework. While I identified one foreign study providing QALY loss estimates for obesity, I was unable to find similar estimates for smoking. Consistent with the prevailing approach in COI studies, I did not include VSL- or QALY-based intangible costs in the core estimates. However, to acknowledge their relevance and illustrate their potential scale, an indicative estimate is provided in Appendix D, using several different methods (VSL, VSLY and DALY for smoking and VSL, VSLY, DALY and QALY for obesity).

3.c VSCC – Alternative approach to count for 3.a and 3.b, might rely on Value of a Statistical Case of Cancer (VSCC).

Here you might discuss Alberini and Scasny 2018; 2021 and Alberini *et al.*, 2023.

A theoretical model to consider morbidity and mortality see the latest papers by Rheinberger, Herrera-Araujo, and Hammitt (2016 on).

Thank you for this valuable suggestion. I agree that the Value of a Statistical Case of Cancer (VSCC) represents a promising welfare-based approach to valuing health outcomes, particularly when both morbidity and mortality effects are involved. As you correctly point out, several recent studies, including Alberini and Ščasný (2018, 2021) and Alberini *et al.* (2023), have applied this methodology in the Czech context and provide useful benchmarks for valuing cancer-related risks.
In the context of this dissertation, I opted not to use the VSCC approach for two main reasons. First, the COI framework applied in Chapters 2 and 3 focuses primarily on decomposing the economic burden into direct and indirect costs (healthcare utilization and productivity losses), consistent with standard practice in applied health economics (e.g., Rice (1967)). Second, the scope of the analysis is broader than cancer and includes multiple obesity- and smoking-related comorbidities, for which no VSCC equivalents currently exist.

4. Attribution of health end-points to smoking

Ideally, one would need ERFs or RRs for illnesses. You rely on RR for mortality and use the RRs to attribute illnesses to smoking. Please justify your approach in Introduction since I miss a logic how RR for mortality can serve as a good proxy for attribution of illnesses (additionally than to cite the four studies).
Let me follow your eq.'s 3.2-3.4 (and assume pFC=0). Then, see my table that shows SAF as a function of RR and pS (where pNS=1-pS).
If RR=1 (mortality for smokers and non-smokers is just the same), how SAF for smokers is always zero regardless of what their share is in a population (no cost attributable to smokers)
If RR=10 (dying is 10-times larger among smokers than it is among non-smokers) and Ps=.5, how one should interpret implied SAF=82%? And if PS=1 (everyone is a smoker), why SAF=90% which is less than 100%?
Just imagine an extreme case with RR=100 for smokers and Ps=.01, then SAF=50%. If the (conditional) survival rate for a given illness is the same for the two populations, why one should attribute 50% of the COI to 1% of population with unconditional risk of dying that is 100-times larger than it is for the 99% of population?

Thank you for pointing this out. I agree that morbidity-specific relative risks (RRs) would be the ideal input for computing smoking-attributable fractions for healthcare costs and absenteeism. However, such RRs were not available for the Czech Republic or comparable populations. In light of this, I followed the approach outlined in the WHO Economics of Tobacco Toolkit: Assessment of the Economic Costs of Smoking (2011), which acknowledges this data limitation and provides guidance on how to proceed in such cases.
Specifically, the toolkit notes that for estimating healthcare costs (p. 46) and productivity losses due to morbidity (p. 62), mortality-based RRs can be used as a proxy when morbidity-specific estimates are unavailable. This practice is based on the assumption that elevated mortality risks reflect a broader increase in disease severity and burden, particularly for major conditions such as cancer, cardiovascular disease, and COPD.
A clarifying note referencing this guidance has now been added to the methodology section of Chapter 3.
As for the interpretation of SAFs: In the introduction, I have included a brief explanation of the logic behind the SAF formula and how it behaves under different values of prevalence and relative risks (RR). For instance, when RR = 10 and the prevalence of smoking is 50%, the resulting SAF of 82% implies that 82% of smoking-related deaths in the population are attributable to the excess risk borne by smokers. This reflects the counterfactual logic behind attributable fractions – i.e., how much of the burden would be avoided if the exposed group had the same risk as the unexposed. More detailed discussion can be found in Appendix to Chapter 1 (subsection Interpretation of smoking-attributable fraction formula)
I hope these additions make the logic of this approach clearer and more transparent. I have also acknowledged these methodological compromises in the limitations section of the chapter.

5. Loss of productivity

It seems to be a commonly accepted approach to value loss of earning by wage; please discuss whether one should take net (after-tax) wage, gross wage, or labour cost (super-gross wage in our case). If you perform BCA and hence call COI as the Social cost of ..., then you should value dW/dS by shadow prices. Discuss this in the Introduction. Use correct terms (depending on which approach you will be following, COI or BCA) in Chapter 2 and Chapter 3.

Thank you for this insightful comment. I have clarified in the revised manuscript that the

study adopts a cost-of-illness (COI) framework rather than a full benefit-cost analysis (BCA) to estimate the economic burden of obesity and smoking, and that the valuation of productivity losses is based on gross wages, consistent with standard practice in COI literature. While I recognize the relevance of using shadow prices or labor costs in BCA contexts, the objective here is to estimate the economic burden of smoking and obesity in descriptive terms. A discussion of this methodological choice and its implications has been added to the introduction and methods section.

6. Interpretation

First, please pay attention for using the term "social costs of ..." (aka BCA) vs. "cost of illness" (the first two components of HPF).

Thank you for pointing this out. In response, I have revised the terminology used throughout the thesis to more accurately reflect the methodological framework. Specifically, I have replaced the term "social costs" with "economic burden" or, where appropriate, simply "costs" to ensure consistency with the cost-of-illness (COI) approach employed in Chapters 2 and 3. These chapters focus only on the first two components of the health production function and the revised terminology now better reflects this scope.

Second, smoking may cause certain illnesses after some time, and here cessation lag and latency are important, see the latest volume in JBCA for latency for cancers. It would be fine to argue that the current price may affect the behaviour of certain groups in the case of incidence-based COI. However, prevalence-based COI refers to patients who are still alive and who are or were likely smokers even 20-30 years ago (their behaviour was affected likely by prices in the past).

Thank you for this important observation. I fully agree that in the context of smoking-related diseases, particularly cancers and chronic conditions, latency and cessation lag are critical considerations. As you rightly point out, prevalence-based cost-of-illness (COI) studies reflect the current burden of disease, which is largely driven by smoking behavior that occurred 20-30 years ago. This has important implications for the interpretation of such estimates, especially when assessing policy effects.
The discussion of this limitation, and its implications for interpreting the results, has been expanded in the revised version of the thesis. In particular, it is now explicitly acknowledged

that the cost estimates presented likely underestimate the true burden of smoking due to declining prevalence over time and the inability to fully reflect historical exposure patterns.

Third, it might be interesting to relate your aggregate to a person not to GDP.
For instance, your aggregated COI (not the social cost!) is 1.6 b€and about 25% of the adult population is obese, hence about 2 mil. people. your aggregate implies 800€per obese and year. One part (xxx1) is a part of GDP, while the second part (xxx2) is a potential GDP, missing due to reduced (labour) productivity.

Thank you, I have incorporated per capita interpretations of the results in both the obesity and smoking chapters. For obesity, the total cost of 1.6 billion EUR implies an average burden of approximately 697 EUR per obese adult in 2018. For smoking, the corresponding per capita burden is approximately 761 EUR per current or former smoker aged 35+ in 2019. These figures are now included in the summary of results sections to complement the GDP-based interpretation and to make the scale of the burden more intuitively accessible. I have also clarified that the direct costs reflect actual healthcare spending (a component of GDP), while the indirect costs represent forgone or potential GDP due to reduced labour productivity and premature mortality.

Fourth, secondary smoking is ignored, so again COI might be quite far from the social cost of smoking.

Thank you for this observation. I agree that secondhand smoke (SHS) represents an important component of the overall societal burden of smoking. In the thesis, SHS is explicitly acknowledged as a relevant cost component, but it is not included in the quantitative estimates due to the absence of reliable data on the number of individuals affected by SHS exposure in the Czech Republic. Existing research suggests that SHS may account for up to 10% of the total costs of smoking (e.g. Koronaiu *et al.* (2019): SHS exposure accounts for 8.9% of the costs of smoking in Greece in 2017; Sung *et al.* (2014): SHS exposure accounts for 8% of total costs in Taiwan in 2010), which implies that the estimates presented in the thesis may be conservative. This limitation is noted in the discussion, and the omission of SHS should be interpreted as a data-driven constraint rather than a conceptual exclusion.

Minor:

1. Avoid using argumentation that something is missing (wrong) because it has relied on subjective values; remember there is no objective value in neoclassical economics; at least in neoclassic econ we follow a consumer sovereignty normative perspective.
2. You used in your presentation several times the term "estimated"; I guess you "calculated" the COI, rather than "estimated" COI since estimation would allow providing a statistical inference of the estimates and I did not see any presented. Please correct the terms in the dissertation.

Thank you for your comment regarding the terminology used in referring to the cost-of-illness (COI) results. You are correct in pointing out that the term "estimate" may suggest formal statistical inference, which was not conducted in this thesis. My intention in using "estimate" was to reflect the inherent uncertainty in the computed costs, which arise from several sources–including limited data availability and necessary modelling assumptions, such as relative risks, discount rates, growth rates, and parameters related to presenteeism.
Nevertheless, I have revised the terminology throughout the dissertation to replace "estimate" with more appropriate alternatives such as "compute," "calculate," or "quantify," in order to more accurately describe the nature of the analysis and align with your recommendation.