Aus dem Deutschen Krebsforschungszentrum Heidelberg

Wissenschaftlicher Stiftungsvorstand: Prof. Dr. med. Michael Baumann

Abteilung Klinische Epidemiologie und Alternsforschung

Leiter: Prof. Dr. med. Hermann Brenner

Regional variations in cancer outcome in Germany – assessing the impact of socioeconomic deprivation and cancer care

Inauguraldissertation

zur Erlangung des Doctor scientiarum humanarum (Dr. sc. hum.)

an der Medizinischen Fakultät Heidelberg

der Ruprecht-Karls-Universität

Vorgelegt von:

Isabelle Finke

Aus Jülich

2021

Dekan: Prof. Dr. med. Hans-Georg Kräusslich

Doktorvater: Prof. Dr. med. Hermann Brenner

Table of contents

List of tables

List of figures

Abbreviations

ASR	age-standardized incidence rate
BMI	Body mass index
BYM	Besag, York and Mollié
CAU	Census area unit
CBG	Census block group
CI	Confidence interval
CIR	Crude incidence rate
CD	Census Collection District
CeT	Census tract
CONCORD-3	Study of global surveillance of trends in cancer survival 2000-2014
CRC	Colorectal cancer
CSS	Cause-specific survival
CoS	Cohort study
CT	Data from clinical trials
DA	Dissemination area
DCO	Death certificate only
EA	Enumeration area
ED	Enumeration district
EDI	European Deprivation Index
ED-SCLC	Extensive disease small-cell lung cancer
ER	Estrogen receptor
EUROCARE-5	European cancer registry-based study on survival and care of cancer patients
EU-SILC	European Union Statistics on Income and Living Conditions survey
FCR	Finnish Cancer Registry
FU	Follow-up length
GESIS	Gesellschaft Sozialwissenschaftlicher Infrastruktureinrichtungen
GIMD	German Index of Multiple Deprivation
GLOBOCAN	Global Cancer Observatory
HR	Hazard ratio
ICD-10	International classification of diseases, 10th revision
IMD	Index of Multiple Deprivation
IND	Individual
INLA	Integrated Nested Laplace Approximation
INS	Insurance
IQR	Interquartile range
KM	Kaplan-Meier
LGA	Local Government Area
LSOA	Lower Super Output Area
MB	Meshblock
mth(s)	month(s)
N	Number of observations
NA	Not available
NCDB	National Cancer Data Base

NL	The Netherlands
NOS	Newcastle-Ottawa-Scale
NRW	North Rhine-Westphalia
NSCLC	Non-small cell lung cancer
NZ	New Zealand
OA	Output Area
OS	Overall survival
PBC	Population-based cohort
PC	Postal code
PCo	Prospective cohort
POA	Postal code area
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
PROSPERO	International prospective register of systematic reviews
Q	Quintile
QS	Quality score
RCo	Retrospective cohort
RDC	Regional Data Center
REG	Registry
RER	Relative excess risk
RKI	Robert Koch-Institute
RS	Relative survival
SCLC	Small-cell lung cancer
SD	Standard deviation
SEER	Surveillance, Epidemiology, and End Results Program
SEIFAs	Socioeconomic Indexes for Areas
SES	Socioeconomic status
SLA	Statistical Local Area
TNM	Tumor, Node, Metastases
UK	United Kingdom
USA	United States of America
wks	weeks
yrs	Years of age
ZB MED	German National Library of Medicine

1 Introduction

1.1 Epidemiology of cancer in Germany

1.1.1 Incidence and mortality

For 2018, the GLOBOCAN project estimated 17.0 million new cancer cases and 9.5 million cancer deaths worldwide (excluding non-melanoma skin cancer), with lung, female breast, colorectal and prostate cancer being the most common cancer sites (Bray et al. 2018). The leading causes of cancer death were lung, colorectal, stomach, and liver cancer (Bray et al. 2018). Although Europe represents only 9.0 % of the global population, it accounts for 23.4 % of the total cancer cases and 20.3 % of the cancer deaths (Bray et al. 2018).

For Germany, the Robert Koch-Institute (RKI) estimated almost 500,000 new cancer cases for both men and women in 2016 (RKI 2019). The age-standardized incidence rates (ASR) were 348.3 and 422.9 cases per 100,000 with a median age at diagnosis of 69 and 70 years for women and men, respectively (RKI 2019). A projection of cancer incidence using German cancer registry data for 27 cancer sites estimated the overall incidence rate to increase by 5.0 % (95 %-credible interval 0.0-13.0 %) and newly diagnosed cases to increase by 23.0 % (95 %-credible interval 17.0-29.0 %) until 2030, the latter mainly driven by demographic change (Stock et al. 2018).

After cardiovascular diseases, cancer is the second most common cause of death in Germany (Statistisches Bundesamt 2017). For 2016, the RKI estimated 230,000 cancer deaths (RKI 2019). The age-standardized mortality rates were 125.1 and 188.3 per 100,000 with a median age at death of 76 and 75 years for women and men, respectively (RKI 2019).

In 2016, the most common cancer sites were breast, colorectal and lung cancer in women and prostate, lung and colorectal cancer (CRC) in men in Germany, being as well the most common cancers among all cancer deaths (RKI 2019). For cancers of the lung (International classification of diseases, 10th revision (ICD-10) C33-C34), ASRs for women and men were 31.4 and 57.5 per 100,000 and mortality rates were 22.6 and 45.7 per 100,000 in 2016, respectively (RKI 2019). From 1995 to 2015, lung cancer incidence and mortality rates in Germany decreased in men, whereas in women, there was an increase for both new diagnoses and the chance of dying of lung cancer (Wienecke and Kraywinkel 2018). For female breast cancer (ICD-10 C50), age-standardized incidence and mortality rates were 112.2 and 23.4 per 100,000

in 2016, respectively (RKI 2019). The implementation of the German mammography screening program from 2005 to 2009 probably resulted in a reduction in late-stage breast cancer incidence at the cost of moderate increase in the diagnosis of earlier stages in women aged 50-69 years (Katalinic et al. 2020). However, mortality in female breast cancer patients decreased by about one fifth to one fourth after implementing the screening program (Katalinic et al. 2020). Regarding CRC (ICD-10 C18-C20), ASRs for women and men were 31.8 and 50.7 per 100,000 and mortality rates were 11.8 and 33.0 per 100,000 in 2016, respectively (RKI 2019). After the implementation of screening colonoscopy as cancer screening program in Germany in 2002, age-standardized CRC (ICD-10 C18-C21) incidence declined in persons over age 55 by 17.0-26.0 % from 2003-2012 (Brenner et al. 2016b). In persons under age 55, CRC incidence decreased by 3.0 % in men and increased by 14.0 % in women (Brenner et al. 2016b). Age-standardized CRC mortality decreased by more than 20.0 % within the same time period (Brenner et al. 2016b).

1.1.2 Survival

According to the global CONCORD-3 study (Global surveillance of trends in cancer survival 2000-2014), 5-year net survival after a cancer diagnosis was highest in the United States (USA), Canada, Australia, New Zealand, Finland, Iceland, Norway, and Sweden (Allemani et al. 2018). Across all cancer sites, survival trends were increasing in most countries from 2000 to 2014 (Allemani et al. 2018). However, 5-year net survival showed wide ranges internationally (Allemani et al. 2018). For example, 5-year net survival for female breast cancer ranged from 66.1 % to 90.2 %, and for lung cancer, survival was in the range of 10.0 % to 20.0 % in most countries (Allemani et al. 2018). Within Europe, the EUROCARE-5 study (European cancer registry-based study on survival and care of cancer patients) showed that relative cancer survival was highest for northern, central, and southern Europe (De Angelis et al. 2014).

For Germany, the RKI estimated the 5-year relative survival (RS) rate for all cancer sites combined to be 65.0 % in women and 59.0 % in men in 2016 (RKI 2019). A study including 11 German population-based cancer registries estimated RS for 24 common and 11 less common cancer sites diagnosed in 2002-2010 (Jansen et al. 2015). For most cancer sites, the prognosis of cancer patients improved from 2002 to 2010, which might be due to improvements in the quality of cancer care on the population level (Jansen et al. 2015).

The RKI estimated the 5-year RS rate in Germany in 2016 to be 87.0 % for female breast cancer, 63.0 % for CRC and 21.0 % for lung cancer (RKI 2019). Regarding female breast cancer, age-standardized RS for German patients improved from 1992 to 2008 (Holleczek et al. 2011). In CRC, 5-year RS rates for patients registered in 11 German cancer registries in 1997-2006 increased over the period 2002-2006 from 60.6 % to 65.0 % (Majek et al. 2012). In lung cancer, 5-year RS rates for patients registered in 11 German cancer registries in 2002-2010 were 20.3 % in women and 15.5 % in men, showing that compared to other cancer sites, survival rates were rather stable since the early 2000s (Eberle et al. 2015).

Regional variation in cancer survival has been investigated in Germany (Geiss and Meyer 2019; Jansen et al. 2012; Nennecke et al. 2014). A comparison between Eastern and Western Germany in patients diagnosed in 1997-2006 revealed that 5-year RS rates were comparable between both regions showing that the former gap in survival of cancer patients in Eastern Germany has been overcome (Jansen et al. 2012). In 2011, a regional comparison across federal states showed no excess variation in 5-year RS for colorectal, lung, female breast, and prostate cancer in relation to the German survival estimate (Geiss and Meyer 2019). A study including patients registered in 11 German cancer registries from 1997-2006 compared 5-year RS rates across urban and rural areas and showed no consistent trend and only little variation across regions. The study reported a slightly better prognosis in female breast cancer patients and male malignant melanoma patients resident in urban regions (Nennecke et al. 2014).

Prognostic factors for cancer patient survival have been discussed frequently in research and can be categorized as patient-related such as age, sex, comorbidities and life-style factors, tumor-related such as stage at diagnosis, grading, or histologic subtype but as well screening, access to cancer care and cancer treatment in accordance with guidelines (Brenner et al. 2016a; Eberle et al. 2015; Majek et al. 2013; Wolters et al. 2015).

1.2 Socioeconomic measures

1.2.1 Definition of individual and aggregated measures

The individual socioeconomic status (SES) of a person is often referred to as social class or social position (Quaglia et al. 2013). In his philosophical theory, Max Weber defined a person's social position on the three domains class, state and power (Weber 1946). Class refers to economic factors, state is determined by the prestige rank of a person within the community and power corresponds to a political context (Quaglia et al. 2013; Weber 1946). In

epidemiology, three indicators corresponding to Weber's definition are used: occupation, education and income (Quaglia et al. 2013). Occupation corresponds to state and covers first public opinion and second the degree of esteem for social class (Quaglia et al. 2013). Education refers to both state and class as it influences the lifestyle and social networks of a person (Quaglia et al. 2013). Lastly, income corresponds to class, lifestyle as well as power (Quaglia et al. 2013). In addition to the three main components of SES, epidemiologic studies use other social determinants such as gender, race, ethnicity, marriage status, or housing status which could be a proxy for occupation, education and income but could also be investigated as factor itself (Quaglia et al. 2013).

If individual SES is not available, aggregated measurements can be applied as a proxy measure (Maier 2017; Schuurman et al. 2007). When these measures are aggregated on area-level, investigations considering the context of the region where a person is resident are possible and would be another reason to use area-based socioeconomic measures (Maier 2017; Quaglia et al. 2013). This can be important for example in health research, where interventions aimed to reduce social inequalities might be implemented on regional level if the health care system is organized accordingly (Geuter et al. 2017). Areas can comprise administrative regions such as municipalities, districts, federal states, or even whole countries which are not explicitly created for research purposes and therefore can have wide ranges in terms of population size (Schuurman et al. 2007). Other examples for pre-defined spatial units are Census Collection Districts (CD, average population: 547 residents) and Statistical Local Areas (SLA, median population: 21,000 residents) in Australia (Tervonen et al. 2017). In some countries, regions were created for statistical purposes such as Lower Super Output Areas (LSOA, mean population: 1,500 residents) in the United Kingdom (Exarchakou et al. 2018) or Zip Code (average population: 30,000), Census Block Group (CBG, average population: 1,000), and Census Tract (CeT, average population: 4,000) in the USA (Krieger et al. 2002). In correspondence to individually measured SES, area-based measures can comprise the percentage of residents with high school diploma, a certain household-income or blue-collar workers (Brenner et al. 1991; Cheyne et al. 2013; Khullar et al. 2015; Quaglia et al. 2013). If social inequalities in health are investigated on the level of whole countries, the GDP (Gross domestic product) expenditure on health for each country could be used as aggregated socioeconomic measure (Evans and Pritchard 2000).

In many countries, several factors are combined to a composite index measure which is ought to reflect the advantage, disadvantage or deprivation of a region (Exarchakou et al. 2018; Tervonen et al. 2017). For example, Australia implemented a set of four indices named Socioeconomic Indexes for Areas (SEIFAs) that comprise relative socioeconomic disadvantage regarding access to material and social resources and the ability for social participation (Tervonen et al. 2017). The data to create the SEIFAs is collected in the Census of Population and Housing every five years (Tervonen et al. 2017). In Europe, the European Deprivation Index (EDI) was created using results from the European Union Statistics on Income and Living Conditions survey (EU-SILC) and census information (Guillaume et al. 2016; Pornet et al. 2012). However, the EDI is not available throughout Europe probably as the socioeconomic information was not available on smaller area levels in all countries (Guillaume et al. 2016). The United Kingdom was one of the first countries, for which a deprivation index was implemented (Quaglia et al. 2013). For example, the Townsend deprivation index was created in 1988 and the Carstairs index in 1991, both based on census data (Carstairs and Morris 1989; Quaglia et al. 2013; Townsend et al. 1988). In the early 2000s, the Index of Multiple Deprivation (IMD) was created by Noble and colleagues (Noble et al. 2006). The IMD was defined as multidimensional, meaning that it summarizes different topics regarding deprivation, so-called domains (Maier 2017). It was based on routinely collected administrative data instead of censuses which makes it easier and faster to update with more recent data (Maier 2017). In Germany, two deprivation indices are available: The German Index of Socioeconomic Deprivation (Hoebel et al. 2018) and the German Index of Multiple Deprivation (GIMD, (Maier 2017)). The latter is described in more detail in the following chapter. In general, deprivation indices have been used frequently in cancer research to investigate social inequalities in cancer incidence, mortality and survival around the world (Aarts et al. 2010; Hoebel et al. 2018; Klein and von dem Knesebeck 2015; Kogevinas and Porta 1997; Manser and Bauerfeind 2014; Miki et al. 2014; Tervonen et al. 2017; Tron et al. 2019).

1.2.2 German Index of Multiple Deprivation

The GIMD is based on data of official statistics and consists of seven single domains (income, employment, education, municipality revenue, social capital, environment, and security deprivation), and a composite index (Maier 2017; Maier et al. 2012). The domains income, employment and education comprise the indicators total revenue by tax payers,

unemployment rate, and residents without vocational training, respectively (Maier et al. 2012). Municipality revenue refers to gross earnings minus expenditure and debts (Maier et al. 2012). Social capital describes net migration change and voter participation in national elections (Maier et al. 2012). Environment refers to areas used by industry and traffic and security comprise traffic accidents and criminal offenses (Maier et al. 2012). Up to now, two editions of this deprivation index are available based on data from 2006 and from 2010 (or the next year available), respectively (Maier 2017; Maier et al. 2012). The GIMD was measured on the level of German administrative district as well as on municipality level (Maier 2017).

The index has been used in various studies to examine social inequalities in health in Germany (Grundmann et al. 2014; Hofmeister et al. 2016; Jansen et al. 2014; Kuznetsov et al. 2012; Maier 2017; Spix et al. 2017). For example, using the GIMD on municipality level, Grundmann and colleagues reported an association between socioeconomic deprivation and the prevalence of type 2 diabetes and obesity (Grundmann et al. 2014). Another study reported an elevated risk of total and premature mortality in districts with highest deprivation compared to districts with lowest deprivation (Hofmeister et al. 2016). But the GIMD has also been used in cancer research (Jansen et al. 2014; Kuznetsov et al. 2012; Spix et al. 2017). Using data from German population-based cancer registries, Jansen and colleagues investigated the association between socioeconomic deprivation and survival after cancer diagnosis (Jansen et al. 2014). The study is described in more detail in the following chapter. The GIMD has been established in current health research to investigate social inequalities on area-level in Germany (Maier 2017).

1.3 Socioeconomic differences in cancer survival

Social inequalities in cancer survival have been investigated and reported for both individual and area-based socioeconomic measures (Aarts et al. 2010; Berglund et al. 2010; Coughlin 2019; Dalton et al. 2019; Dalton et al. 2015; Galvin et al. 2018; Jansen et al. 2020; Jansen et al. 2014; Singer et al. 2017; Tervonen et al. 2017). This chapter briefly introduces to individual socioeconomic differences in cancer survival but is then mainly focused on area-based measures.

The three mostly studied individual socioeconomic measures are education, income and occupation (Quaglia et al. 2013). A study from Denmark investigated differences in RS for income groups among patients diagnosed with the 15 most common cancer sites and all

cancers combined in 1987-2009 (Dalton et al. 2019). The study showed significantly lower 5-year RS for 9 out of 15 cancer sites in the lowest compared to the highest income group (Dalton et al. 2019). A systematic review restricted to patients aged 65 years or older reported lower cancer-specific and overall survival (OS) in patients with lower income or lower SES in general (Galvin et al. 2018). Associations between individual SES and cancer survival have in particular been shown in patients diagnosed with the most common cancers such as breast (Coughlin 2019; Lundqvist et al. 2016), lung (Berglund et al. 2010; Dalton et al. 2015), and colorectal cancer (Aarts et al. 2010; Manser and Bauerfeind 2014). In Germany, a multicenter cohort study including 1,633 cancer patients investigated the association between the individual socioeconomic measures education, job grade, job type, and equivalence income and survival with 10-year follow-up (Singer et al. 2017). The study reported lower survival in lower socioeconomic groups regarding job type and equivalence income and no association with education and job grade (Singer et al. 2017).

Area-based socioeconomic inequalities in cancer survival have been reported in several countries and for several cancer sites showing that cancer patients living in affluent regions have better survival compared to those living in deprived regions (Coughlin 2019; Jansen et al. 2014; Klein and von dem Knesebeck 2015; Kogevinas and Porta 1997; Lundqvist et al. 2016; Manser and Bauerfeind 2014; Quaglia et al. 2013; Tervonen et al. 2017). Such associations have even been reported in countries with comprehensive access to health care for all population groups, such as Australia (Lyle et al. 2017), England (Exarchakou et al. 2018) and France (Tron et al. 2019). An English study investigated cancer survival trends and socioeconomic inequalities measured by the IMD on Lower-layer Super Output Area level (Exarchakou et al. 2018). The authors reported improved 1-year net survival from 1996-2013 for most cancer sites but persisting differences between deprivation groups with lower survival in most deprived areas (Exarchakou et al. 2018). A French study including all registered cancer sites used the EDI and reported lower 5-year net survival for patients resident in most compared to least deprived areas for almost all cancers (Tron et al. 2019). Regarding breast cancer, two systematic reviews included studies with different socioeconomic measures and reported inequalities in cancer survival for instance for neighborhood disadvantage, area-based education or occupation and the unemployment rate (Coughlin 2019; Lyle et al. 2017). Two other systematic reviews focused on CRC (Aarts et al. 2010; Manser and Bauerfeind 2014). Both reviews reported lower survival in patients resident in areas categorized to be of

lower SES, irrespective if it was a single socioeconomic measure or combined into an index (Aarts et al. 2010; Manser and Bauerfeind 2014). A French study investigated OS after lung cancer diagnosis and socioeconomic deprivation on municipality level (Chouaid et al. 2017). The authors showed a gradual decrease in 2-year OS the higher the deprivation of the municipality was in both metastatic and non-metastatic lung cancer patients (Chouaid et al. 2017). A study conducted in Florida (USA) reported socioeconomic disparities in OS in patients diagnosed with non-small cell lung cancer (NSCLC) (Tannenbaum et al. 2014). The socioeconomic deprivation was measured as percentage of residents in a CeT living below the federal poverty line (Tannenbaum et al. 2014). Internationally, there has been a wide range of studies investigating social inequalities in cancer survival but only few studies have been conducted in Germany regarding this issue.

Five studies investigated area-based socioeconomic differences in cancer survival in Germany (Brenner et al. 1991; Jansen et al. 2020; Jansen et al. 2014; Jansen et al. 2021a; Jansen et al. 2021b). The first study was conducted in the early 1990ies in the federal state of Saarland and investigated the SES on municipality level and the association with RS in CRC patients (Brenner et al. 1991). The analysis showed lower survival in patients resident in municipalities of lower SES (Brenner et al. 1991). In a more recent study, the association between regional socioeconomic deprivation and cancer survival was analyzed for 25 cancer sites using data from population-based cancer registries covering 200 of 439 districts (median population: 126,000 residents in 2006) in Germany (Jansen et al. 2014). Results showed that survival in 2002-2006 was comparable among deprivation groups except lower RS for patients living in the most deprived districts. These survival differences persisted after adjustment for stage and were strongest for cancer sites with good prognosis and in the first months after diagnosis. However, measurement of socioeconomic deprivation at county level does not take potential variation of socioeconomic deprivation across municipalities within counties into account. Furthermore, possible interventions to reduce differences in cancer survival could be organized on municipality level. To approach this issue, a following study investigated socioeconomic deprivation on municipality level (median population: 2,200 residents) and CRC overall survival by using data from three population-based clinical cancer registries in Regensburg, Dresden and Erfurt (Jansen et al. 2020). The authors reported lower 5-year OS of about 4.8 % units in most deprived compared to least deprived municipalities, which persisted after adjustment for stage, surgery and screening colonoscopy uptake rates (Jansen et al.

2020). Differences in socioeconomic deprivation were largest in younger patients, rectal cancer patients, stage I, in the latest period of diagnosis, and with longer follow-up (Jansen et al. 2020). Another study estimated the number of avoidable deaths attributable to municipality-level socioeconomic deprivation in cancer survival in 2013-2016 using data from 11 German population-based cancer registries (Jansen et al. 2021b). The authors reported that 3.0 % of all excess deaths per year could have been avoided if RS in all regions was similar with the RS in the least deprived regions (Jansen et al. 2021b). Lastly, one study investigated socioeconomic inequalities in RS in Hamburg (1.84 million residents) for colorectal, lung, female breast, and prostate cancer for the period 2014-2018 (Jansen et al. 2021a). The study found strong associations of a lower cancer survival in most deprived city districts which were partly attenuated by stage adjustment for breast and prostate cancer (Jansen et al. 2021a).

Previous studies have shown that the strength of association might depend on the resolution of the deprivation index (Krieger et al. 2002; Tervonen et al. 2017; Woods et al. 2005). An Australian study investigating deprivation differences in cancer survival reported stronger associations when using the smaller area-level of CDs (average population: 547 residents) instead of SLAs (median population: 21,000 residents) (Tervonen et al. 2017). Hazard ratios (HR) for the most deprived regions compared to the least deprived regions were 1.25 (95 % confidence interval (CI) 1.22-1.29) for CD level and 1.16 (95 % CI 1.13-1.20) for SLA level, both adjusted for age, sex, year of diagnosis, remoteness, country of birth, cancer site and stage (Tervonen et al. 2017). A previous Australian study compared a socioeconomic index on CD level with the larger Local Government Area level (LGA, average population: 35,954 residents) and reported similar results regarding cancer survival (Stanbury et al. 2016b). A study conducted in the USA showed fewer social gradients or reverse gradients for most investigated health outcomes (e.g., cause-specific mortality rates, cancer incidence rates) when using socioeconomic measures on the larger zip code level (average population: 30,000) compared to smaller CBG (average population: 1,000) or CeT (average population: 4,000) measures (Krieger et al. 2002).

To investigate the underlying reasons for social disparities in cancer survival, it might be helpful to look at a possible pathway from socioeconomic deprivation to inequalities in cancer survival (Quaglia et al. 2013). A lower individual as well as area-based SES could impact timely access to health care (Quaglia et al. 2013). For example, due to the allocation of resources,

waiting lists, difficulties in transport, or lack of communication with health care personnel, there could be a delay in seeking medical advice after initial symptoms (Quaglia et al. 2013). This could lead to a delay in the diagnosis of a cancer and therefore a later stage at diagnosis affecting a patient's prognosis (Quaglia et al. 2013). In succession, cancer patients resident in a more deprived area could get less, later or different treatment compared to patients resident in less deprived areas, leading again to inequalities in cancer survival (Quaglia et al. 2013). Hence, it is necessary to examine clinical prognostic factors and cancer care as possible reasons for social disparities in cancer survival.

1.3.1 Differences with regard to clinical prognostic factors

Differences in comorbidities, life style factors, utilization of primary and secondary prevention and overall access to health care between socioeconomic groups could be the origin of disparities in clinical factors that affect the prognosis of a patient (Quaglia et al. 2013). More deprived areas could have less health care resources which might lead to fewer offers regarding disease prevention and larger distances to the nearest health care professional (Quaglia et al. 2013). Probably one of the most important clinical factors regarding socioeconomic differences in the prognosis of patients is stage at diagnosis (Quaglia et al. 2013; Woods et al. 2006). An Australian study showed a higher chance of being diagnosed with distant stage when resident in a more deprived area for several cancer sites (Tervonen et al. 2017). A study from England reported that inequalities in breast cancer survival by deprivation could be reduced by one-third if adverse stage distributions in patients resident in the most compared to the least deprived areas would be eliminated (Li et al. 2016). Studies from other countries support these findings by showing an impact of stage at diagnosis on the association between socioeconomic deprivation and breast cancer survival (Coughlin 2019; Lundqvist et al. 2016; Yu 2009). In lung cancer patients, a French study showed similar associations between area-based socioeconomic deprivation and OS for both metastatic and non-metastatic disease (Chouaid et al. 2017). A Danish study revealed that stage at diagnosis could only partly explain the association between a lower individual SES and lower OS in lung cancer patients (Dalton et al. 2015).

A later stage at diagnosis might not only be the result of reduced access to diagnostic facilities but also inequalities of access to screening programs (Quaglia et al. 2013). It has been shown that socioeconomic deprivation could be associated with a lower rate of adherence to

screening offers (Aarts et al. 2011; de Klerk et al. 2018; Quaglia et al. 2013), although literature is still inconclusive (Lyle et al. 2017). A Dutch study showed a gradual increase in attending the mammography screening program with increasing individual educational status (Aarts et al. 2011). Furthermore, women in the lower education group had an unfavorable stage at diagnosis compared to other women, irrespective of the mode of detection (Aarts et al. 2011). However, a review including only Australian studies reported no differences in mammography screening attendance by SES (Lyle et al. 2017). A review revealed lower participation rates in CRC screening programs among lower socioeconomic groups (de Klerk et al. 2018). Although screening attendance and the following stage at diagnosis showed to be important factors with regard to socioeconomic inequalities in cancer survival, it is not a thorough explanation for these disparities (Quaglia et al. 2013).

Biological characteristics of the tumor have been investigated to explain the association between socioeconomic deprivation and cancer survival (Woods et al. 2006). In breast cancer, tumor characteristics such as morphology, grade, estrogen receptor status (ER) and triple negative breast cancer subtype have been shown to be prognostic factors (Allemani et al. 2004; Pierga et al. 2003; Twelves et al. 1998) and have at least some impact on social disparities in cancer survival (Kaffashian et al. 2003; Lian et al. 2014; Thomson et al. 2001; Woods et al. 2006). Whereas in CRC, anatomic site, morphology and grade were not different across socioeconomic deprivation groups (Lyratzopoulos et al. 2003).

In Germany, Jansen and colleagues (Jansen et al. 2014) reported no change in RS differences between socioeconomic deprivation groups when additionally adjusting for stage at diagnosis. However, information on stage at diagnosis was only available for 52.0 % of the patients (Jansen et al. 2014). A more recent German study on CRC survival included more complete data regarding the tumor from clinical cancer registries (Jansen et al. 2020). Effect estimates increased when adjusting for stage at diagnosis but social disparities persisted and associations were stronger in stage I cancer (Jansen et al. 2020).

Despite the reported socioeconomic differences in stage at diagnosis, in many studies and for most cancer sites, tumor extension could not entirely explain socioeconomic disparities in cancer survival (Quaglia et al. 2013; Tervonen et al. 2017). In addition, biological characteristics could only explain some part of the association (Woods et al. 2006).

1.3.2 Differences with regard to cancer care

Differences in comorbidities, age at diagnosis, biological characteristics of the tumor and stage at diagnosis could affect the chosen cancer treatment and lead to social disparities in cancer survival (Li et al. 2016; Quaglia et al. 2013). Social inequalities in cancer treatment and care have been reported for several cancers and in several countries (Quaglia et al. 2013; Woods et al. 2006).

Patients resident in more deprived regions received less often cancer treatment according to guidelines (Aarts et al. 2010; Lyle et al. 2017; Quaglia et al. 2013; Riba et al. 2019). A systematic review on social disparities in CRC treatment showed consistently that colon cancer patients in the lower socioeconomic group had a lower chance of receiving curative treatment such as chemotherapy, radiotherapy and surgery (Aarts et al. 2010). Regarding rectal cancer patients, this was partly true for chemotherapy and radiotherapy (Aarts et al. 2010). A study from the USA showed that breast cancer patients with lower household income received more often mastectomy instead of breast conserving therapy and less often immediate breast reconstruction or systemic therapy (Riba et al. 2019). A review supporting these findings revealed that breast cancer patients resident in more deprived areas were more likely to receive mastectomy and less likely to receive reconstructive surgery compared to patients resident in least deprived areas (Lyle et al. 2017).

These differences in cancer therapy could affect social inequalities in cancer survival (Quaglia et al. 2013; Woods et al. 2006). After adjustment for patient- and tumor-related factors and cancer treatment, some studies still reported social differences in cancer survival (Berglund et al. 2012; Jansen et al. 2020; Le et al. 2008; Li et al. 2016; Riba et al. 2019; Yu 2009), whereas other studies reported no associations after adjustment (Quaglia et al. 2013; Rapiti et al. 2009). A study from the USA reported lower cancer-specific survival in breast cancer patients in the lower area-based socioeconomic group with attenuated but remaining associations after adjusting for stage at diagnosis and first course treatment (Yu 2009). This was supported by a review investigating social inequalities in breast cancer survival (Lundqvist et al. 2016). In contrast, an English study reported no change in breast cancer survival disparities across area-based deprivation mediated through differential treatment (Li et al. 2016). A Swiss study including prostate cancer patients showed that patients with lower individual SES had a lower cancer-specific survival compared to the higher socioeconomic group but differences wore off

after adjusting for patient-, tumor- and treatment-factors (Rapiti et al. 2009). OS was lower in colon or rectal cancer patients resident in more deprived regions in the USA, even after adjusting for race, stage at diagnosis, surgery, chemotherapy and radiotherapy (Le et al. 2008). In lung cancer patients, OS was higher in patients living in more deprived regions in England irrespective of the stage of diagnosis and adjustment for resection, chemotherapy and radiotherapy, however, social disparities decreased (Berglund et al. 2012).

One German study including CRC patients reported persisting disparities in OS between deprivation groups after adjusting for utilization of surgery (Jansen et al. 2020). Subgroup analyses restricting to patients receiving guideline concordant cancer treatment revealed that inequalities were mostly still present (Jansen et al. 2020).

Although tumor characteristics and cancer treatment could not entirely explain social inequalities in cancer survival, these factors belong to the most important influencing factors within the association between socioeconomic deprivation and cancer survival (Quaglia et al. 2013; Woods et al. 2006).

1.4 Aims of the dissertation

First, a comprehensive summary of the current literature on socioeconomic differences in lung cancer survival is given, with a focus on the impact of aggregation and adjustment level.

The second aim was to investigate the association between area-based socioeconomic deprivation on municipality level (median population of included area: 1,194 residents in 2006) (Statistisches Bundesamt 2006) and cancer survival for 25 cancer sites in Germany by using data from population-based cancer registries. As complementay aims, it was investigated whether deprivation-associated inequalities changed over time and whether the association between area deprivation and cancer survival depends on the age, sex or stage at diagnosis of the cancer patients.

The third aim was to investigate possible reasons for social disparities in cancer survival in Germany. To accomplish this, the association between area-based socioeconomic deprivation on municipality level (median population of included area: 2,200 residents in 2006) (Statistisches Bundesamt 2006) and cancer survival was investigated by using data from lung and breast cancer patients registered in three German population-based clinical cancer registries. As clinical cancer registries provide more comprehensive data on clinical factors and therapy, it was examined whether the association between area deprivation and lung or breast cancer survival depended on factors related to patient characteristics, clinical prognostic factors or utilization of cancer therapy.

The fourth aim was to explore if socioeconomic differences in cancer survival are comparable when using either individual or area-based information on SES. It is assumed that the association of an individual socioeconomic measure is diluted when using an area-based measure instead (Woods et al. 2005). Therefore, it was investigated if individual or area-based education were associated with CRC survival by using data of the nationwide population-based Finnish cancer registry (FCR). Finally, these results were discussed in relation to area-based deprivation differences in cancer survival in Germany.

2 Methods

2.1 Systematic review and meta-analysis[1]

The systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al. 2010) and the extended version for equity-focused systematic reviews PRISMA-E 2012 (Welch et al. 2016). This review has been registered in the international prospective register for systematic reviews PROSPERO (www.crd.york.ac.uk/PROSPERO, registration number: CRD42017072607).

2.1.1 Literature Search

The main information sources for the literature search were four databases: Medline/PubMed (1966 to December 6, 2017), Web of Science (Science Citation Index Expanded, Social Science Citation Index, 1945 to December 7, 2017), The Cochrane Library (1992 to December 6, 2017) and GESIS Sowiport (1910 to December 8, 2017). The online portal Sowiport was organized by the GESIS Leibniz Institute for the Social Sciences (GESIS 2018) and included several social science related databases until its termination in December 2017. For the search strategy, a combination of key words regarding lung cancer survival and SES was applied. The detailed search strategies for all databases including the respective thesaurus terms are displayed in Table 1. In addition, reference lists of included papers have been searched.

Table 1 Search strategies

Database	Search strategy
Cochrane Library	((MeSH descriptor: [Mortality] explode all trees) OR (MeSH descriptor: [Survival] explode all trees) OR (MeSH descriptor: [Survival Rate] explode all trees) OR (MeSH descriptor: [Disease-Free Survival] explode all trees) OR mortality OR survival) AND ((MeSH descriptor: [Lung Neoplasms] explode all trees) OR (MeSH descriptor: [Carcinoma, Non-Small-Cell Lung] explode all trees) OR (MeSH descriptor: [Small Cell Lung Carcinoma] explode all trees) OR (small-cell lung cancer) OR (non-small cell lung cancer) OR (lung AND (cancer OR carcinoma OR neoplasm))) AND (MeSH descriptor: [Healthcare Disparities] explode all trees) OR (MeSH descriptor: [Health Status Disparities] explode all trees) OR (MeSH descriptor: [Socioeconomic Factors] explode all trees) OR (MeSH descriptor: [Social Class] explode all trees) OR (MeSH descriptor: [Income] explode all trees) OR (MeSH descriptor: [Occupations] explode all trees) OR socioeconomic OR deprivation OR disparit* OR segregation OR

[1] The different parts of this chapter are based on and were presented in the article Finke et al. 2018. The author's contribution to the different parts is declared in section 7.1.

Database	Search strategy
	education OR income OR occupation OR (social AND (status OR class OR position OR inequalit*))
PubMed	(mortality OR survival OR (”mortality"[Subheading]) OR ("Mortality"[Mesh] OR "Survival"[Mesh]) OR ("Survival Analysis"[Mesh])) AND ((lung AND (Cancer OR carcinoma OR neoplasm)) OR “small-cell lung cancer” OR “non-small cell lung cancer” OR ("Lung Neoplasms"[Mesh])) AND ((social AND (status OR class OR position OR inequalit*)) OR socioeconomic OR deprivation OR disparit* OR segregation OR education OR income OR occupation OR ("Healthcare Disparities"[Mesh]) OR ("Health Status Disparities"[Mesh]) OR ("Social Class"[Mesh]) OR ("Socioeconomic Factors"[Mesh]) OR ("Social Determinants of Health"[Mesh]))
Sowiport	(Alle Felder[a]:(survival OR mortality)) AND (Alle Felder[a]:(lung AND cancer)) AND (Alle Felder[a]:(socioeconomic OR deprivation OR social OR segregation OR education OR income OR occupation))
Web of Science	(survival OR mortality) AND ((lung AND (cancer OR carcinoma OR neoplasm)) OR “small-cell lung cancer” OR “non-small cell lung cancer”) AND (socioeconomic OR deprivation OR disparit* OR segregation OR education OR income OR occupation OR (social AND (status OR class OR position OR inequalit*)))

[a]Alle Felder (engl. all fields)

2.1.2 Inclusion and exclusion criteria

2.1.2.1 Population

To be eligible, studies had to investigate a population of patients with a primary diagnosis of lung cancer. If other cancer sites were additionally investigated, studies were only included if results for lung cancer patients were reported separately.

2.1.2.2 Exposure(s)

The focus of the search was on the main socioeconomic factors education, income and occupation as explanatory variable, measured either on an individual or area-based level. As many area-based studies used combined SES measurements, also called indices, all combined measures or indices were additionally included. Categorical and continuous measurements of socioeconomic measures were included.

2.1.2.3 Outcome

The primary outcome of interest was survival after lung cancer diagnosis reported stratified by socioeconomic group. The focus was on effect estimates from survival regression models (Cox or Poisson), 1-, 3- or 5-year survival rates and median survival time after diagnosis. Other measures of survival were additionally included. The description of the results in the text focused on the regression models.

2.1.2.4 Types of studies

Observational studies published in a peer-reviewed journal in English or German language were eligible for inclusion in the review. Non-original articles, such as guidelines, comments, book-chapters, editorials, reviews and methods-papers were excluded. There was no further restriction regarding the period of publication or the study design.

2.1.2.5 Meta-analysis

To be eligible for inclusion in the meta-analysis, included studies had to fulfill further criteria. First, a study had to report HRs including respective 95 % CIs. Second, the studies should report on the same socioeconomic measure in a comparable manner to be able to combine the results in a meta-analysis. Third, socioeconomic measures had to be reported as categorical variables to identify low SES and high SES groups. Lastly, studies had to have a quality score of at least 6 out of 8 stars (for definition of the score see quality assessment below). This criterion was defined after writing the review protocol but before study results were summarized and interpreted. A cut-off of 6 was chosen by trading off the aim to include as many studies as possible against the aim to guarantee a high quality of the included studies. However, sensitivity analyses were additionally conducted including all studies irrespective of the quality score. In case of overlapping populations, it was decided to hierarchically include the study with the most comprehensive inclusion of all stage groups, the longest period of diagnosis, and the longest follow-up period.

2.1.3 Study selection and data extraction/screening

Titles, abstracts, and full texts retrieved were screened by the author of this dissertation. If no full text was available, studies were excluded if published before 1980, otherwise retrieved from The German National Library of Medicine (ZB MED) (ZB-MED 2018). EndNote software X7 was used to remove duplicates, retrieve full text articles, and manage citations. Data extraction of relevant information from included studies was performed by the author

of this dissertation and additionally by another reviewer for each study. Disagreements were resolved through discussion with another member of the review team. If relevant information was not reported in a study, the corresponding author was contacted via email. Sixteen authors were contacted and ten answered to the request. Data items extracted from articles included the following: First author, publication year, country, study type, study setting, sample characteristics (n, age, gender), measure of SES (education, income, occupation, index), level of measurement (individual/area-based), outcome measure, prognostic factors, risk of bias evaluation and main results. If a study used two different SES measurements separately, results for both measures were extracted. Model results were reported for the full model including all adjustments.

2.1.4 Quality assessment

To assess the methodologic and reporting quality of included studies, a modified version of the Newcastle-Ottawa-Scale (NOS) was used (Wells et al.). The NOS consists of seven items to judge the quality of a study regarding the selection and comparability of study groups and ascertainment of the outcome (cohort studies) or exposure (case-control studies). One star was awarded for each item, except the comparability item which was modified so studies controlling for age in their analysis were awarded with one star and one additional star if any other factor was controlled for. In total, a study could be awarded with a maximum of 8 stars. The coding manual was not restricted to a specific follow-up length, as the assessment of an adequate follow-up period refers to the study aim of the respective article. For example, if a study reported three months survival rates, the follow-up period had to be at least three months. The coding manual of the modified NOS can be found in Appendix A.

2.1.5 Statistical analysis and sensitivity analysis

Random effects models were computed and heterogeneity was assessed across studies by using I^2 and Q statistics (DerSimonian and Laird 1986). The inverse variance method was used to assign the weight of each study in the analysis. For each study, HRs of the lowest SES group were compared with the highest SES group as a reference. This was necessary as the categorizations of socioeconomic measures were very heterogeneous between the studies. Subgroup analyses were performed if possible, by adjustment for smoking status, stage and treatment. To assess the possible risk of bias and heterogeneity across studies included in the meta-analyses, funnel plots were generated and Begg's and Egger's test of plot asymmetry

was performed. All analyses were performed in the R statistical software (version 3.3.1) by using the metafor library (version 2.0-0).

2.2 Data sources/study population[2]

2.2.1 German epidemiological cancer registries

For this register-based cohort study, data were used from seven population-based cancer registries in Germany covering 10 of 16 German federal states (Schleswig-Holstein, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Bavaria, Saarland, Brandenburg, Mecklenburg-Western Pomerania, Saxony, and Thuringia, Figure 1). A common record layout was used to collect the data, which were checked for plausibility and pooled for analysis. Data of those districts with a proportion of death certificate only (DCO) cases of less than 13 % in 2002-2014 were used and covered a population of about 31.9 million residents in 2006 (Table 2) (Statistisches Bundesamt 2006). Patients aged ≥ 15 years with invasive malignant tumors of 25 most common cancer sites (which account for approximately 94 % of all cancers; codes of the ICD-10: C00-C14, C15, C16, C18-21, C22, C23-C24, C25, C32, C33-C34, C43, C49, C50 (females), C53, C54, C56, C61, C62, C64, C67, C71-C72, C73, C81, C82-C85, C90, C91-C96) who have been diagnosed between 1998 and 2014 were included into the analyses. DCO or autopsy only cases were excluded from the survival analyses (Figure 2).

Table 2 Overview on years of diagnosis, case numbers and death certificate only proportions by cancer registry

Cancer Registry	Years of Diagnosis	Cases		
		Including DCO	Excluding DCO	% DCO cases
Schleswig-Holstein[a]	1998-2014	141,453	118,356	16.3 %
Lower Saxony	2003-2014	555,553	497,952	10.3 %
North Rhine-Westphalia[b]	1998-2014	236,360	217,738	7.5 %
Rhineland-Palatinate[c]	1998-2014	170,676	144,368	15.4 %
Bavaria[d]	2002-2014	384,433	349,916	9.0 %
Saarland	1998-2014	102,251	97,149	4.1 %
Brandenburg	1998-2014	228,336	208,507	8.7 %
Mecklenburg-Western Pomerania	1998-2014	155,049	143,456	7.5 %
Saxony	1998-2014	402,939	376,507	6.5 %
Thuringia	1998-2014	202,442	179,598	11.3 %

[a]Districts Flensburg, Kiel, Neumünster, North Frisia, East-Holstein, Plön, Rensburg-Eckernförde, Schleswig-Flensburg; [b]Region Münster; [c]Districts Koblenz, Bad Kreuznach, Birkenfeld, Cochem-Zell, Mayen-Koblenz, Rhein-Hunsrück-Kreis, Trier, Bernkastel-Wittlich, Eifelkreis Bitburg-Prüm, Vulkaneifel, Trier-Saarburg, Mainz, Worms, Alzey-Worms, Mainz-Bingen; [d]Regions Swabia (Aichach Friedberg, Augsburg city, Augsburg district), Upper Franconia (Bayreuth city, Bayreuth district, Forchheim), Middle Franconia (Erlangen Hochstadt, Erlangen,

[2]The different parts of this chapter are based on and were presented in three articles: Finke et al. 2020; Finke, Seppä et al. 2021; Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

Nürnberg, Fürth), Upper Palatinate (all districts), Upper Bavaria (all districts except Berchtesgadener Land, Mühldorf am Inn, Landsberg am Lech, Eichstädt, Ingolstadt, Pfaffenhofen a.d. Ilm, Neuburg-Schrobenhausen), and Lower Bavaria (Landshut city, district Landshut); Abbreviation: DCO, death certificate only.

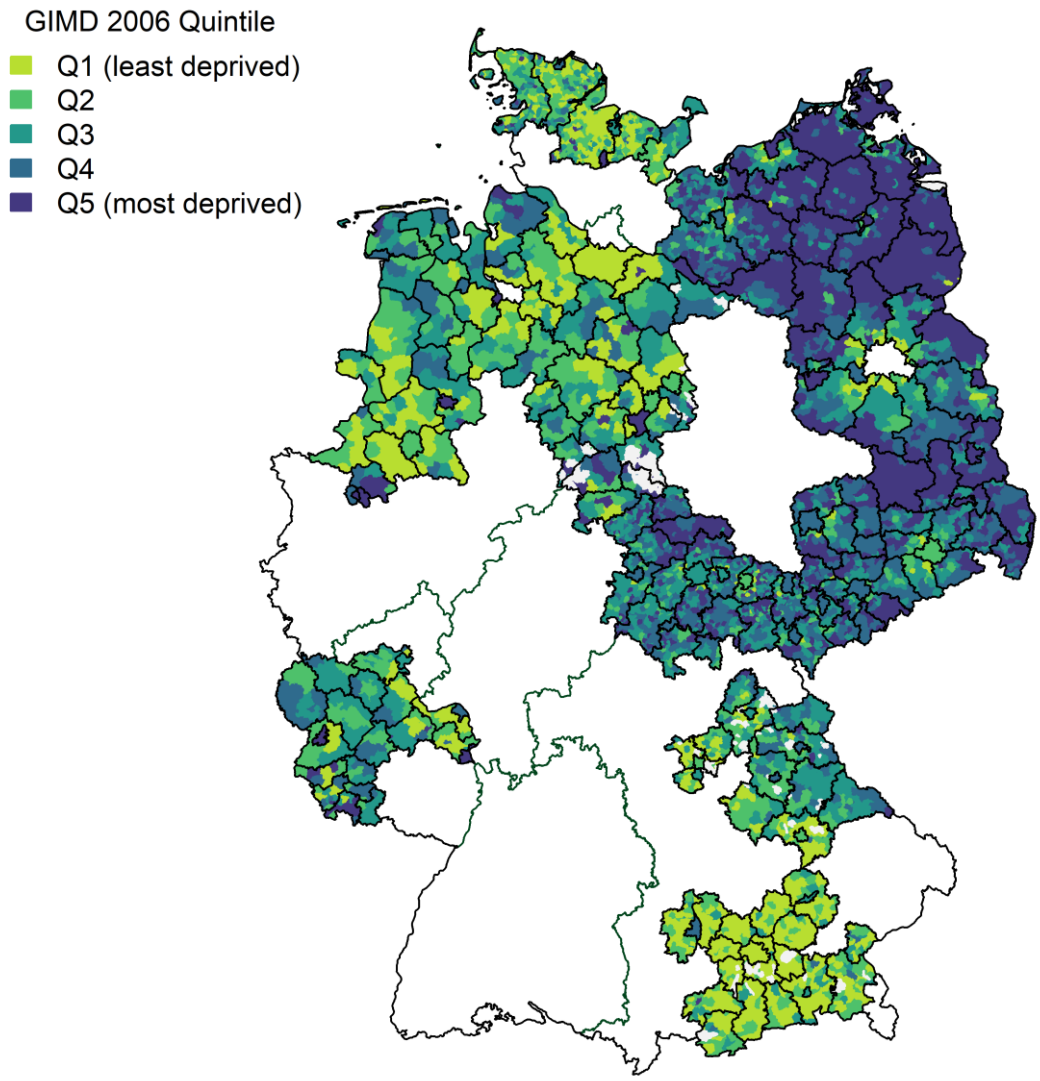

Figure 1 Distribution of GIMD quintiles across German regions included in the analysis on area-based deprivation differences in cancer survival. Regions in white were not included in analyses. Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile

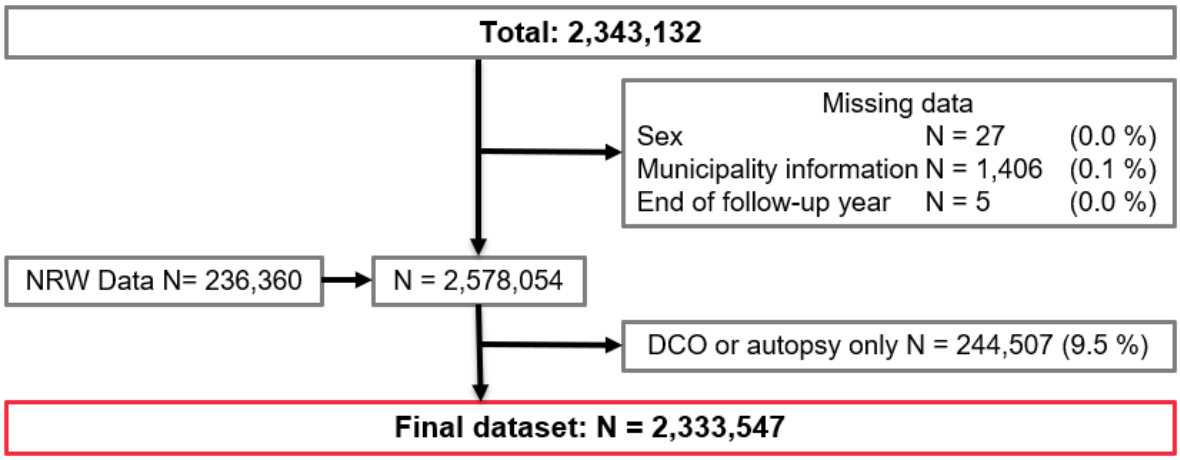

Figure 2 Flow diagram of exclusions for the analysis on area-based deprivation differences in cancer survival. NRW data was categorized (person years and number of deaths by GIMD quintile, year of diagnosis, year of follow-up, age, sex and stage at diagnosis) and contained no missing data. Abbreviations: DCO, death certificate only; GIMD, German Index of Multiple Deprivation; N, number of observations; NRW, North Rhine-Westphalia

2.2.2 German clinical cancer registries

For this retrospective cohort study, data were used from three regional population-based clinical cancer registries in Germany (located in Regensburg, Erfurt, and Dresden and covering parts of the German states Bavaria, Thuringia and Saxony, respectively, Figure 3). Nationwide clinical cancer registration is currently being implemented for all German regions. However, during the conduction of this analysis, only few registries were able to provide cancer data for a longer period of diagnosis as well as sufficient data completeness and quality which is why these three clinical cancer registries were chosen to be included. The three cancer registries cover regions in the south and east of Germany (Population size ≈ 4 million residents in 2015) (Statistisches Bundesamt 2019). The cities of Dresden (523,058 residents), Erfurt (204,994 residents) and Regensburg (135,520 residents) comprise 13.4 %, 5.2 % and 3.5 % of the total underlying study population, respectively (Statistisches Bundesamt 2019). The catchment areas of the Erfurt and Regensburg registries include five other cities with a population of 42,000 to 51,000 residents. Death certificate or autopsy only cases were excluded (Figures 4 (lung cancer) and 5 (breast cancer)). Patients at the age of 15 years or older and resident in the catchment areas of one of the above-mentioned registries with a malignant primary tumor of the lung (ICD-10 C34) diagnosed in 2000-2015 or female breast cancer (ICD-10 C50) diagnosed in 2006-2016 were eligible for the analyses.

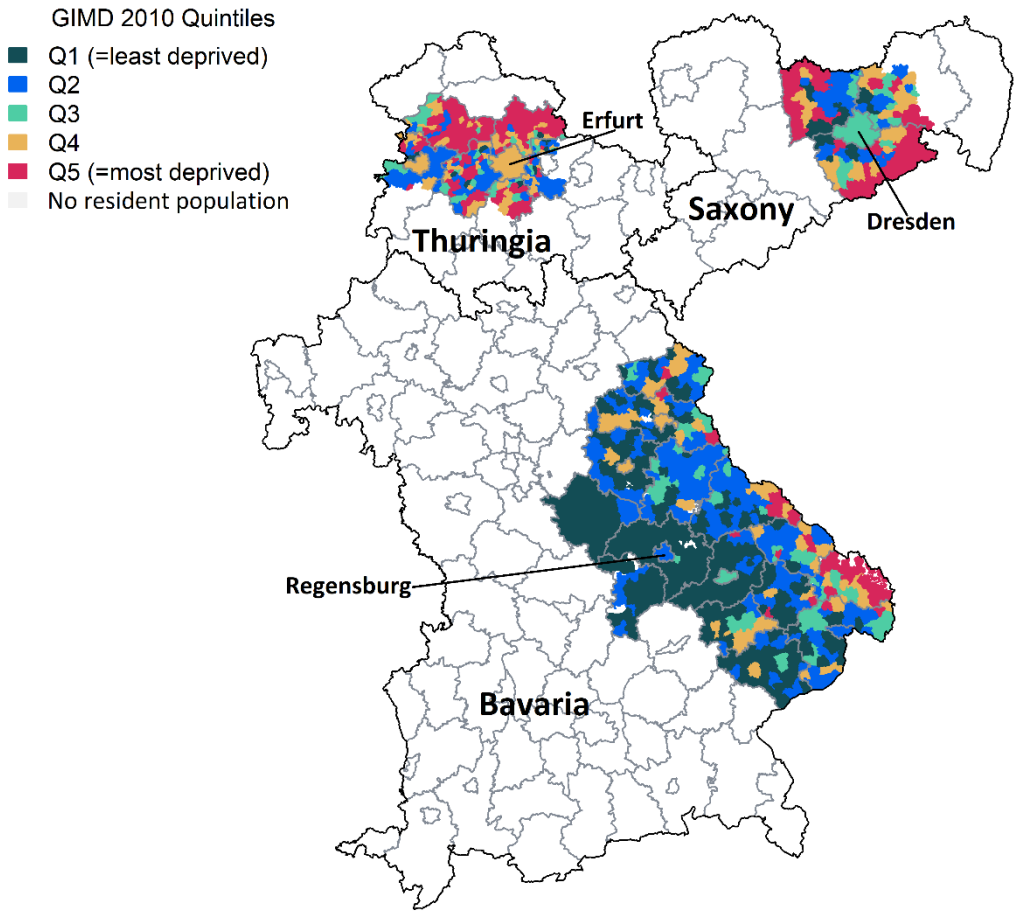

Figure 3 GIMD 2010 Quintiles for all included municipalities within the three German federal states Thuringia, Bavaria and Saxony. Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile.

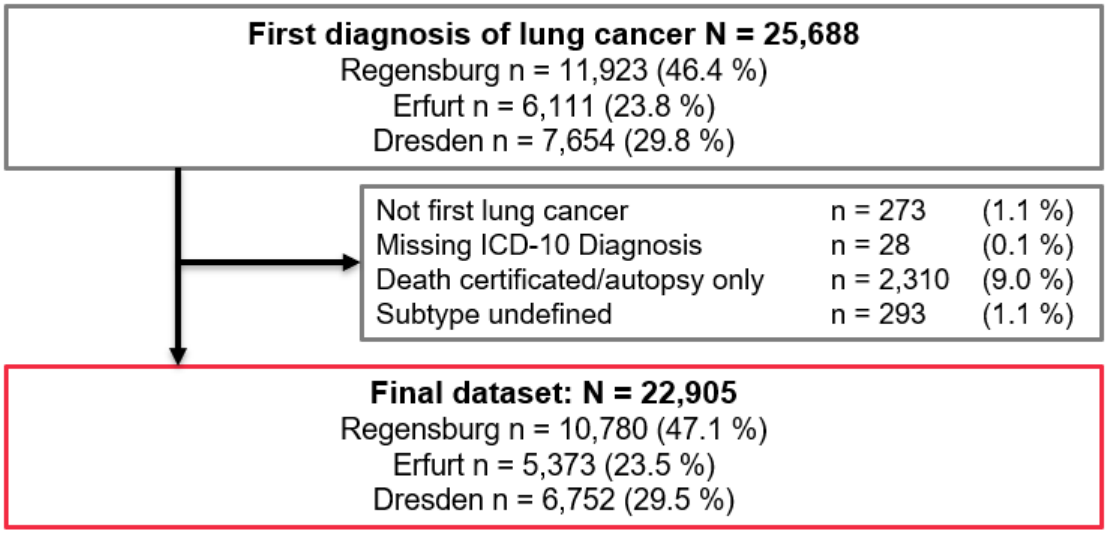

Figure 4 Flow diagram of inclusions and exclusions for a study population of lung cancer patients registered in three German clinical cancer registries. Abbreviations: ICD, International Classification of Diseases; N, number of observations.

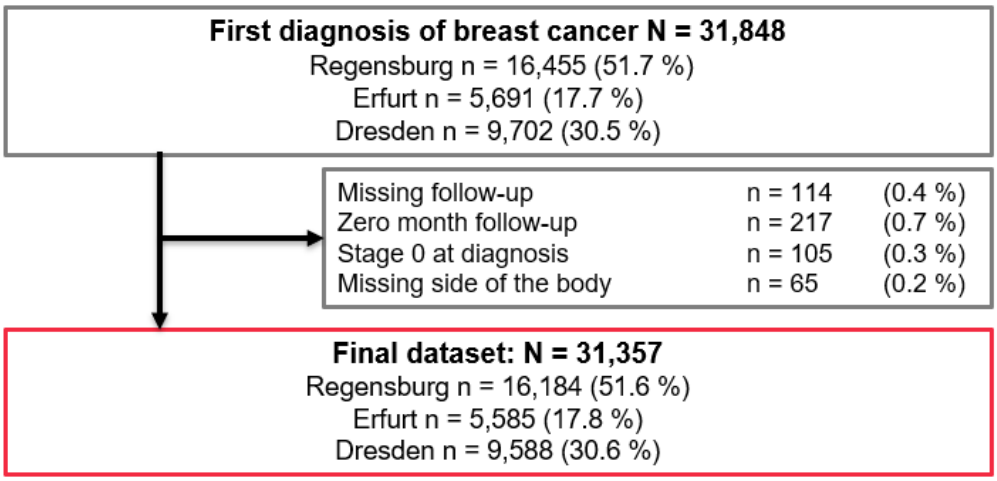

Figure 5 Flow diagram of inclusions and exclusions for a study population of breast cancer patients registered in three German clinical cancer registries. Abbreviation: N, number of observations.

2.2.3 Finnish Cancer Registry

Inclusion criteria comprised patients diagnosed with CRC (ICD-10 C18-20) in 2007-2016, followed up in 2012-2016 and registered in the FCR which is estimated to cover 96.0 % of all solid malignant tumours diagnosed in Finland (Figure 6) (Leinonen et al. 2017). Patients had to be at least 25 years old at diagnosis until which age most persons reached their highest level of education. Cases identified solely by death certificates or autopsy were excluded (1.9 % since 2007).

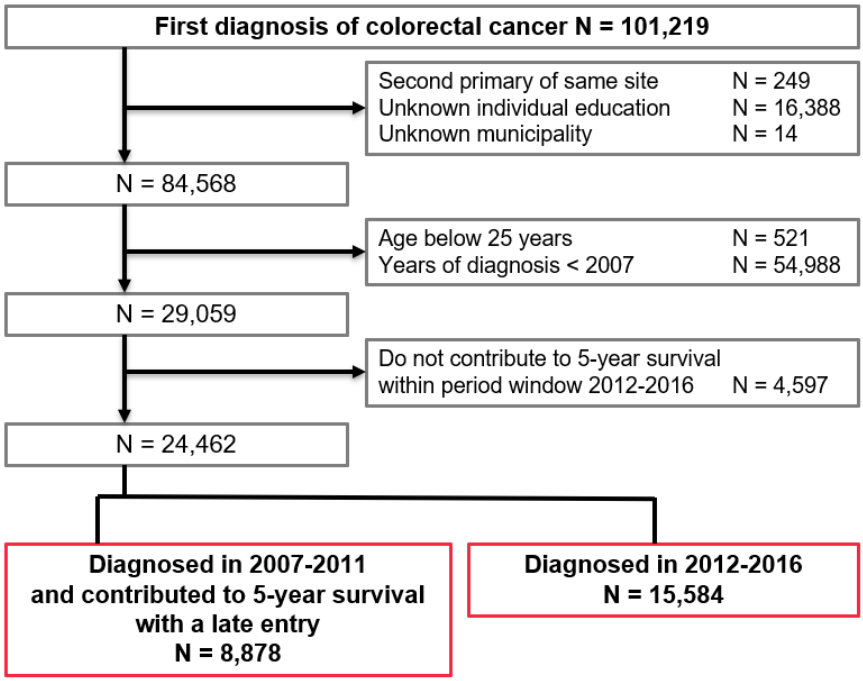

Figure 6 Flow chart of included patients diagnosed with colorectal cancer in Finland in 1953-2016. Abbreviation: N, number of observations.

2.3 Socioeconomic measures[3]

2.3.1 German Index of Multiple Deprivation

In the analyses using German cancer registry data, the area-based socioeconomic deprivation of the patients was assessed using the GIMD (Maier et al. 2012) on municipality level. All included municipalities were assigned the composite index as deprivation score.

2.3.1.1 Epidemiological cancer registries

In the analysis including epidemiological cancer registry data, area-based deprivation status of the patients on municipality level was assessed using the GIMD 2006 (Fairburn et al. 2016; Maier 2017). Scores of the composite index were assigned to all included municipalities of the study area and new deprivation quintiles were computed over these municipalities so that the underlying population was distributed evenly over the quintiles. These deprivation quintiles were assigned to each patient according to the municipality of residence at the time of diagnosis. In the catchment areas of included registries, there were 6,524 municipalities with a median population of 1,194 residents (range 8-1,294,608, interquartile range (IQR): 517-3,494 residents) in 2006 (Statistisches Bundesamt 2006). Figure 1 shows a map of Germany displaying the distribution of GIMD quintiles across all municipalities included.

2.3.1.2 Clinical cancer registries

In the analyses including clinical cancer registry data, the GIMD 2006 for all patients diagnosed before January 1, 2009, and the GIMD 2010 for all patients diagnosed on January 1, 2009 or later was used. For the composite index of the GIMD, deprivation quintiles based on the underlying population of the included municipalities were calculated so that each GIMD quintile contains approximately 20 % of the total population in the three registry regions. To overcome the uneven distribution of the quintiles when stratifying the GIMD by the three cancer registries, region-specific deprivation quintiles were created separately for each registry. The quintiles were built according to the same method as the quintiles across the total study area but the large cities Dresden and Erfurt were assigned a separate category. These region-specific quintiles were used for stratified analyses by cancer registry in the lung cancer analysis. All patients were assigned to a deprivation quintile according to the municipality of residence at the time of diagnosis. In the catchment areas of included

[3] The different parts of this chapter are based on and were presented in three articles: Finke et al. 2020; Finke, Seppä et al. 2021; Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

registries, there were 792 municipalities with a median population of 2,205 residents (IQR 1,138-4,276; range 137-504,795) in 2006 and 779 municipalities with a median population of 2,189 residents (IQR 1,137-4,303; range 128-523,058) in 2010 (Statistisches Bundesamt 2019). Table 3 shows cutoffs for the categorized GIMD quintiles and the original GIMD quintiles and Figure 3 shows a map of the categorized 2010 GIMD quintiles over all included municipalities.

Table 3 Cutoffs for GIMD quintiles categorized according to catchment areas of three German clinical cancer registries and GIMD quintiles originally categorized according to the whole of Germany.

	Deprivation quintile Range of GIMD values					
GIMD version and registry	**Q1 (Least deprived)**	**Dresden/Erfurt**	**Q2**	**Q3**	**Q4**	**Q5 (Most deprived)**
Categorized GIMD 2006						
All registries	4.73-17.00	-	17.01-17.75	17.80-21.53	21.55-26.06	26.08-57.20
Dresden	8.90-17.28	17.59	18.53-22.65	22.67-25.09	26.03-32.57	32.99-46.82
Erfurt	9.83-20.13	20.07	20.34-24.28	24.33-25.96	26.14-27.79	27.96-57.20
Regensburg	4.73-15.22	-	15.23-17.55	17.55-21.31	21.33-25.56	25.70-39.57
Categorized GIMD 2010						
All registries	4.94-17.86	-	17.87-24.10	24.15-26.06	26.17-30.64	30.65-60.44
Dresden	10.37-20.08	26.06	20.33-26.98	27.12-31.86	32.02-38.87	39.05-47.24
Erfurt	12.09-24.38	26.17	24.39-29.44	29.51-32.67	32.38-36.93	37.22-60.44
Regensburg	4.94-14.20	-	14.34-18.24	18.25-22.46	22.59-26.30	26.32-43.89
GIMD 2006	2.22-12.35	-	12.35-17.22	17.23-22.59	22.59-29.99	30.00-70.44
GIMD 2010	1.64-11.61	-	11.61-16.40	16.40-22.15	22.15-30.95	30.96-74.01

Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile.

2.3.2 Education

For analyses of the Finnish cancer registry data, information on education was retrieved from Statistics Finland (TK-53-675-17) (Statistics Finland 2019b). Individual education was categorized into three groups (basic, secondary, high) based on the most recent education information prior to the cancer diagnosis. High education included lowest level tertiary, lower-degree level tertiary, higher-degree level tertiary, and doctorate or equivalent level (lasting typically 13 years or more). Secondary education included upper secondary level (10-12 years) and basic education included anything below (<10 years). Area-based education was defined as the proportion of residents with basic education only by municipality and available by calendar year. The population data were sorted by the average proportion of basic educated residents from 2012-2016 and categorized into four groups such that the overall population size in each group of municipalities was similar (Q1-Q4, Q1: low education and Q4: high education). These quartiles were applied to the patient data. Sensitivity analyses were

conducted by categorizing area-based education as the proportion of residents with high education for each municipality.

2.4 Statistical analyses[4]

2.4.1 Overview analysis of data from epidemiological cancer registries in Germany

Period analysis was used to calculate RS for each of the 25 most common cancer sites (Brenner et al. 2004). RS quantifies survival of cancer patients relative to expected survival in the overall population. Expected survival was estimated using the Ederer II method (Ederer and Heise 1959) and life tables stratified by age, sex, calendar period, and area-based socioeconomic deprivation. Life tables were derived from population and mortality data on municipality level (RDC 2018a; RDC 2018b). Population and mortality data were aggregated according to GIMD quintiles from which life tables were calculated.

For each cancer site and GIMD quintile, five-year age-standardized RS was estimated for the period 2012-2014. Age-standardization was conducted following the International Cancer Survival Standards (Corazziari et al. 2004). For colorectal, lung, breast and prostate cancer, age-, sex- and stage-specific survival was calculated additionally. Analyses including all cancer sites combined additionally adjusted for case mix (Storm et al. 2010). Furthermore, trend analyses of age-standardized five-year RS for the time periods 2003-2005, 2006-2008, 2009-2011 and 2012-2014 were conducted. Additional analyses comprised short-term survival (3-month and 1-year) as well as 5-year survival conditional on 1-year survival. Differences in cancer survival with respect to quintiles of the composite index of area-based deprivation were tested for statistical significance by model-based period analysis adjusted for follow-up time, age, and stage (Brenner and Hakulinen 2006). Models adjusting for stage included only patients with available stage information, all other models included the total study population. All analyses were carried out with SAS software (version 9.4), using publicly available and commonly used macros for period analysis as in previous studies (Brenner et al. 2002; Brenner and Hakulinen 2006; Jansen et al. 2014).

Due to data protection provisions, the cancer registry North Rhine-Westphalia could not provide individual record data of the cancer patients. Therefore, SAS scripts for analyses were

[4] The different parts of this chapter are based on and were presented in three articles: Finke et al. 2020; Finke, Seppä et al. 2021; Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

provided to the registry to sum up person years and number of deaths by GIMD quintile, year of diagnosis, year of follow-up, age, sex, and stage at diagnosis. These data were then incorporated in the respective analysis.

In sensitivity analyses, age- and sex-specific survival was calculated only for patients with available stage information of their tumors. To consider that some registries provided data only for years of diagnosis starting after 1998, trend analysis were repeated as sensitivity analyses by including only registries which provided data for all years of diagnosis. In an additional sensitivity analysis, the main analysis was repeated adjusting for either federal state or East/West-Germany, respectively.

2.4.2 Analyses of data from clinical cancer registries in Germany

2.4.2.1 Covariates

Cancer registries provided information on age, sex, place of residence, year of diagnosis, tumor-related variables, vital status of cancer patients, and primary treatment, which referred to first treatment of the primary tumor. During data quality checks, strong differences in treatment utilization proportions across registries and calendar periods were detected which could not be excluded to be based on differences in the completeness of treatment registration and might result in biases in regional analyses. However, if the treatment variable explicitly indicated that a specific therapy was actually given, this information was expected to be reliable. Treatment factors for subgroup analyses were used by restricting the sample to patients receiving specific treatments. Additionally, cancer registry (Dresden, Erfurt, Regensburg) was included as adjustment or stratification variable in the models.

For lung cancer, tumor-related variables comprised stage at diagnosis (I, II, III, and IV), histology (SCLC and NSCLC) and grading (low/intermediate, high, undetermined). Primary treatment was defined as either receiving surgery, chemotherapy or radiotherapy (treatment combinations were not considered).

For breast cancer, tumor-related variables comprised stage at diagnosis (I, II, III, and IV), grading (low, intermediate, high, undetermined), and ER status (positive or negative). Primary treatment was defined as surgery, radiotherapy, chemotherapy, and hormone therapy. As almost all patients received surgery, this variable was not considered as a covariate.

2.4.2.2 Outcome

Lung cancer

OS was computed from date of cancer diagnosis to death from any cause. Vital status was ascertained using death certificates and information from the registration offices. Patients lost to follow-up before death or still alive at the last vital status assessment were right-censored at the date of the last vital status assessment or end of 2015 whichever came first.

Breast cancer

RS was computed using period analysis (Brenner et al. 2004). Expected survival was estimated using the Ederer II method (Ederer and Heise 1959) based on life tables stratified by age, sex, calendar period and deprivation quintile on municipality level. Life tables were derived from population- and mortality data on municipality level aggregated according to GIMD quintiles (RDC 2018a; RDC 2018b). Patients were right-censored at the date of the last vital status assessment or end of 2016 (whichever came first).

2.4.2.3 Statistical methods and analyses

Lung cancer

Demographic and clinical characteristics by area-based deprivation quintile were described and distribution across deprivation quintiles were compared using Chi-square tests. Missing data on stage, grading, subtype, chemotherapy and localization were imputed using Multiple Imputation by Chained Equations in R (van Buuren and Groothuis-Oudshoorn 2011). The imputation model included: cancer registry, sex, age, ICD-10 diagnosis, year of diagnosis, month of diagnosis, stage at diagnosis (single TNM variables and summary stage), histological subtype, localization, grading, chemotherapy, radiotherapy, surgery, GIMD (overall and region-specific), municipality code, event variable, and survival time estimated by Nelson-Aalen estimator. Using 40 iterations, 30 complete datasets were generated. Convergence of the models was checked graphically. The datasets were analyzed separately and results were pooled according to Rubin's rules in SAS using PROC MIANALYZE (Mulla et al. 2009). There were no differences in the distribution of the variables before and after imputation, except for grade (Table 4). Slightly more patients were categorized into high grade after imputation.

OS curves by area-based deprivation quintile were computed with the Kaplan-Meier method. The median follow-up length was estimated with reverse Kaplan-Meier method (Shuster 1991). Cox proportional hazards regression was used to investigate the association between

area-based deprivation and survival in detail. Various models were fitted and compared: The base model included adjustment for age, sex and year of diagnosis. The second model additionally included cancer subtype and grading. In a third model, cancer stage was added. Using the third model, subgroup analyses were conducted by restricting the patient sample to patients who received specific treatments. Additionally, subgroup analyses were performed stratified by patient and tumor characteristics. Results were visualized by showing adjusted survival curves which are estimated using marginal survival functions (Zhang et al. 2007). An additional fourth model adjusted for registry. In a sensitivity analysis, the Cox models were calculated by using a category for Dresden city additionally to area-based deprivation quintiles. To account for immortal time bias, the analysis stratified by treatment was repeated using fixed follow-up start dates at 30, 60, and 90 days after diagnosis. Additionally, patients who received their first treatment more than one year after diagnosis were excluded. Multiple imputation was conducted in R (Version 3.5.2) (R-Core-Team 2013), all other analyses were conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

Table 4 Study characteristics before and after multiple imputation.

	Before multiple imputation	After multiple imputation
	%	%
Stage at diagnosis		
I	16.2	16.8
II	7.9	7.6
III	26.3	26.4
IV	49.5	49.3
Missing	10.8	-
Histological subtype		
NSCLC		
Adenocarcinoma	30.2	30.2
Squamous cell carcinoma	31.0	30.9
Other	21.5	21.5
SCLC	17.4	17.4
Missing	0.1	-
Grading		
Low/intermediate	50.0	44.4
High	50.0	55.6
GX or missing	37.5	-
Chemotherapy		
Yes[1]	50.6	50.5
No[2]	49.4	49.5
Missing	6.7	-

Abbreviations: NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer;
[1]Includes: „initiated, but discontinued“, „intended“; [2]Includes: „contraindication“, “No”

Breast cancer

The distributions of patient, tumor and therapy characteristics stratified by area-based deprivation quintile were described and compared using Chi-square tests. The main outcome, five-year RS, was estimated for the calendar period 2011-2016. Age-standardization was conducted following the International Cancer Survival Standards (Corazziari et al. 2004). RS for 1 to 5 years of follow-up by socioeconomic deprivation was displayed in a figure. Relative excess risks of death (RER) stratified by socioeconomic deprivation quintiles were computed for 5-year RS by model-based period analyses adjusted for age and year of diagnosis in the basic model. The second model additionally included stage at diagnosis. In the third model, grading and ER status were added. The third model was additionally calculated for stage subgroups and the subgroups of stage I to III patients receiving either hormone therapy (estrogen receptor positive only), chemotherapy or radiotherapy. The therapy subgroup analyses included only patients who received their first therapy within one year after diagnosis. Analyses stratified by cancer registry were conducted. Furthermore, cancer registry was added as a covariate to the third model for the total study population. Model-based analysis was repeated including cancer registry without adjusting for the analysis-specific GIMD quintiles. Both models (including cancer registry but with and without analysis-specific GIMD quintiles) were calculated for all stage and therapy subgroups described above. In a sensitivity analysis, Dresden city was added as additional category to the deprivation quintiles to consider the large population size compared to other municipalities. All analyses were conducted in SAS 9.4 (SAS Institute Inc., Cary, NC, USA).

2.4.3 Analysis of data from the Finnish Cancer Registry

2.4.3.1 Covariates

Age at diagnosis was categorized into five groups: 25-44, 45-54, 55-64, 65-74, and 75+ years. Region specific variables included 313 municipalities (median population in 2016: 6,068 residents; IQR: 2,854-14,575) and 21 hospital districts (median population in 2016: 173,244 residents) (Statistics Finland 2019c). Stage at diagnosis was defined as unknown, local stage (UICC (Union International Contre le Cancer) stages I and II) and non-local stage (UICC stages III and IV). Cancer site was categorized as colon (C18) or rectal/rectosigmoid (C19-20) cancer. Urbanity was defined as urban, semi-urban and rural municipalities according to the proportion of people living in urban settlements (urban >90 %, semi-urban 60-<90 %, rural

<60 %, details see Statistics Finland (Statistics Finland 2020)). Follow-up time in years was included as intervals: from 0 to <3 months, 3 months to <1 year, and annual intervals from 1 to 5 years.

2.4.3.2 Statistical methods and analyses

All analyses were stratified by sex and education using individual and area-based education, respectively. Number and proportions of patients by individual and area-based education were calculated for all covariates, as well as crude and age-standardized incidence rates for the total population and hospital districts. Patients were followed up from diagnosis until death or emigration within the period window 2012–2016, and survival times were censored at 5 years. Age-standardized 5-year RS was calculated using Ederer II method and the period approach (Brenner and Gefeller 1996). Population mortality data were retrieved from Statistics Finland stratified by sex, age, calendar year, education and hospital district (Statistics Finland 2019a).

RER were estimated between education groups by using the generalized linear model with a Poisson error structure (Dickman et al. 2004). The basic model included education, age, follow-up time and interaction terms between age and follow-up time. Models were fitted including individual and area-based education separately as well as models including multiplicative effects of RERs of both measures. In addition, a series of models were fitted including region (hospital and municipality), stage at diagnosis, cancer site and urbanity to investigate changes in the estimates of the association of education with survival. Regional variation in survival was modelled using random effects. The hospital district specific effects were drawn from a common normal distribution. Variation between municipalities were described by a BYM (Besag, York and Mollié) model that includes both a spatially structured effect and an unstructured normally distributed effect (see (Seppä et al. 2019) for details). The Integrated Nested Laplace Approximation (INLA) approach was used in the estimation (Seppä et al. 2019).

In sensitivity analyses, area-based education was recategorized by the proportion of high educated residents instead of low education and survival analyses including modelling were repeated. Missing data on stage at diagnosis was imputed using Multiple Imputation by Chained Equations in R (van Buuren and Groothuis-Oudshoorn 2011) and the analyses of the basic model and the analyses adjusted for region and stage were repeated. The imputation model included: education, age, cancer site, stage at diagnosis, urbanity, event variable, and

survival time estimated by Nelson-Aalen estimator. Using 40 iterations, 15 complete datasets were generated. Convergence of the models was checked graphically. The datasets were analysed separately and the pooled results were based on the pooled posterior simulations of the 15 analyses. The distribution of stage at diagnosis before and after imputation was similar with slightly a higher proportion of non-local stage after imputation (Table 5).

Table 5 Distribution of stage at diagnosis before and after the imputation by sex and education for colorectal cancer patients diagnosed in Finland in 2007-2016.

	Distribution of stage (%)					
	Men			Women		
	Unknown	**Local**	**Non-local**	**Unknown**	**Local**	**Non-local**
All patients	23.3	28.6	48.1	24.7	26.9	48.4
Unknown excluded		37.3	62.7		35.8	64.2
Unknown imputed		34.7	65.3		34.2	65.8
Individual education						
Basic	22.9	28.2	48.9	24.8	27.1	48.1
Unknown excluded		36.6	63.4		36.0	64.0
Unknown imputed		34.1	65.9		34.0	66.0
Secondary	23.6	28.8	47.5	25.0	26.4	48.7
Unknown excluded		37.8	62.2		35.1	64.9
Unknown imputed		35.1	64.9		34.5	65.5
High	23.6	29.3	47.1	24.1	27.3	48.5
Unknown excluded		38.4	61.6		36.0	64.0
Unknown imputed		35.5	64.5		34.6	65.4
Area-based education						
Q1	23.8	28.8	47.4	24.9	26.8	48.4
Unknown excluded		37.8	62.2		35.6	64.4
Unknown imputed		34.6	65.4		33.9	66.1
Q2	23.0	29.7	47.4	23.4	29.0	47.6
Unknown excluded		38.5	61.5		37.9	62.1
Unknown imputed		36.6	63.4		36.5	63.5
Q3	21.3	28.7	50.0	23.5	27.0	49.5
Unknown excluded		36.5	63.5		35.2	64.8
Unknown imputed		33.8	66.2		33.9	66.1
Q4	24.9	27.1	48.0	27.4	24.6	48.0
Unknown excluded		36.0	64.0		33.9	66.1
Unknown imputed		33.4	66.6		32.5	67.5

3 Results

3.1 Systematic review and meta-analysis[5]

3.1.1 Study selection and characteristics

Based on the search strategy, the initial search resulted in 5,532 publications potentially relevant for the systematic review (Figure 7). After title and abstract screening, 196 articles were selected for full-text screening. Assessment of the full-texts led to the exclusion of 117 articles, mainly due to not investigating survival after lung cancer or not using a measure of education, income, occupation or an index. Fifteen publications were identified by reviewing of reference lists of included articles (Campbell et al. 2000; Chirikos et al. 1984; Coleman et al. 2004; Fujino 2007b; Gorey et al. 1997; Greenwald et al. 1994; Jansen et al. 2014; Jeffreys et al. 2009; Kwak 2017; Lipworth et al. 1970; Pokhrel et al. 2010; Rachet et al. 2010; Sloggett et al. 2007; Smailyte et al. 2016; Zhang-Salomons et al. 2006). In total, 94 articles (Tables 6 and 7) were included in the qualitative synthesis and 17 of these were eligible to be included in the meta-analyses (Aarts et al. 2013; Berglund et al. 2010; Chang et al. 2012; Clement-Duchene et al. 2016; Dalton et al. 2015; Hussain et al. 2008; Johnson et al. 2014; Khullar et al. 2015; Kravdal 2000; Niu et al. 2010; Pagano et al. 2010; Tannenbaum et al. 2014; Wang et al. 2017a; Wang et al. 2017b; Yeole 2005; Yeole and Kumar 2004; Yim et al. 2012).

Characteristics of included studies are shown in Tables 6 and 7. There were 23 studies reporting on socioeconomic measures on individual level (Table 6), 70 studies reporting on area-based level (Table 7) and one study reporting on both levels (Greenwald et al. 1994) (Table 7). One study included both individual and aggregated measures and performed a multilevel analysis (Greenwald et al. 1994) (Table 7). Most studies have been published within the last ten years. Studies on individual SES measures used mostly data from Scandinavia, the USA and Italy, while the majority of studies including area-based SES measures used data from the USA, Great Britain and Australia/New Zealand. Data sources for cancer survival were usually national cancer registries but also cohort studies and clinical trials (Di Maio et al. 2012; Herndon et al. 2008). Most studies reported on all types of lung cancer, but 20 studies restricted analyses to non-small-cell lung cancer (NSCLC) patients (Aarts et al. 2013; Aarts et al. 2015; Berglund et al. 2010; Booth et al. 2010; Caposole et al. 2014; Currow et al. 2014; Di

[5]The different parts of this chapter are based on and were presented in the article Finke et al. 2018. The author's contribution to the different parts is declared in section 7.1.

Maio et al. 2012; Erhunmwunsee et al. 2012; Greenwald et al. 1994; Greenwald et al. 1998; Johnson et al. 2014; Johnson et al. 2016; Khullar et al. 2015; Lara et al. 2014; McMillan et al. 2017; Melvan et al. 2015; Ou et al. 2007; Ou et al. 2008; Pagano et al. 2010; Tannenbaum et al. 2014; Wang et al. 2017b) and three studies were restricted to small-cell lung cancer (SCLC) patients (Lara et al. 2017; Ou et al. 2009; Wang et al. 2017a).

Regarding individual SES, 16 studies measured educational attainment, eight studies measured income and eight studies assessed the occupation of the patients. Studies investigating area-based SES most often used an index (42 studies) or income measures (30 studies) with diverse levels of aggregation from postal codes in The Netherlands (approximately 8-17 households) (Aarts et al. 2015; Louwman et al. 2010; Schrijvers et al. 1995a) to comparisons of whole countries (Evans and Pritchard 2000; Vercelli et al. 2006).

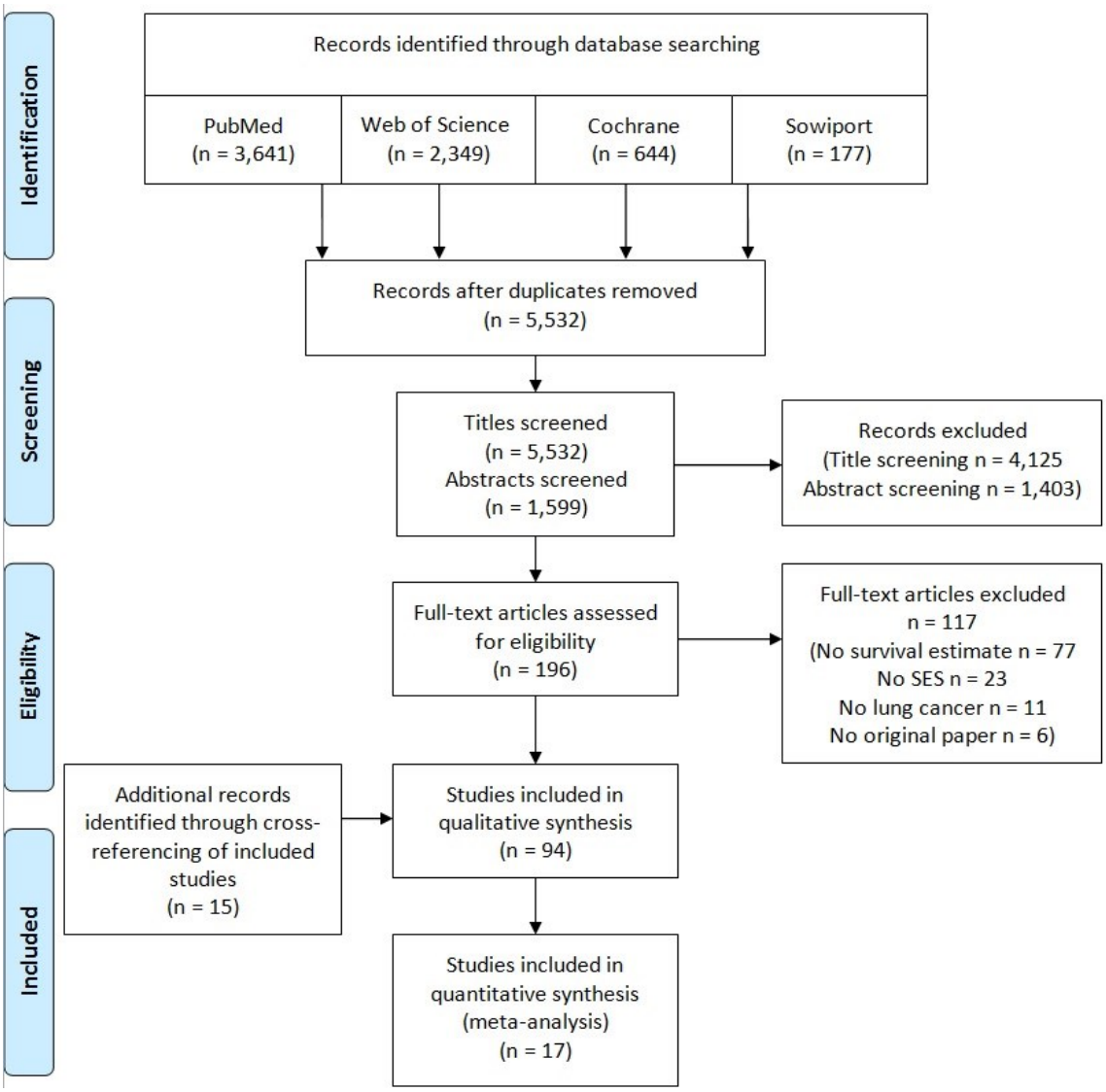

Figure 7 PRISMA flow diagram of study selection process for a systematic review and meta-analysis on socioeconomic differences and lung cancer survival. Abbreviations: N, number of observations; SES, socioeconomic status.

Table 6 Characteristics of included studies with individual measurements of socioeconomic status.

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				Outcome						Adjustment[4]					QS
											Survival								
				Education	Income	Occupation	Index	HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
Europe, north																			
(Dalton et al. 2008), PBC (REG)	Denmark	1994-2003, FU: 2006, 30-79 yrs	21492	3	3	3,6[5]				1,5,KM		X		X	X				8
(Dalton et al. 2015), PBC (REG)	Denmark	2004-2010, FU: 2011, 51-81 yrs	13045	3	3			X			X			X	X	X		X[a]	8
(Pokhrel et al. 2010), PBC(REG)	Finland	1971-2005, FU: 2005, ≥25 yrs	66014	3						5		X	X	X	X				8
(Kravdal 2000), PBC (REG)	Norway	1955-1986, FU: 1960-1991, 50-79 yrs	NA[6]	4		14[7]		X						X	X	X		X[b]	7
(Skyrud et al. 2016), PBC (REG)	Norway	2002-2011, FU: 2013, ≥30 yrs	24565	3	3							X[8]		X	X	X		X[c]	8
(Berglund et al. 2010), PBC (REG)	Sweden	1996-2004, FU: 2006, 30-94 yrs	3370 (NSCLC)	3	2	2		X		1,3			X	X	X	X	X	X[d]	8
(Hussain et al. 2008), PBC(REG)	Sweden	1990-2004, FU: 2004, ≤30 yrs	17936	4				X					X	X	X			X[e]	7
(Vågerö and Persson 1987), PBC (REG)	Sweden	1961-1979, FU: 1979, 20-64 yrs	7817			3				5,KM		X			X				7
Europe, other																			
(Grivaux et al. 2011), PCo	France	2000, FU: 2005-2006, all ages	5447			7				5	X								4
(Di Maio et al. 2012), CT	Italy	1996-2005 (conduction of trials), FU: median 26.3 mths, 29-86 yrs	1680 (NSCLC)	2				X	X	KM	X				X	X		X[f]	4
(Pagano et al. 2010), PBC (REG)	Italy	2000-2003, FU: 2006, all ages	2259 (NSCLC)	3				X			X			X	X	X		X[g]	8
(Pastorino et al. 1990), PBC (REG)	Italy	1976-1979, FU: ≥ 9 yrs, 34-85 yrs	222			3				5	X								6
(Smailyte et al. 2016), PBC (REG)	Lithuania	2001-2009, FU: 2009, 30-74 yrs	8812	3						5		X		X	X				8
(Aarts et al. 2013), PBC (REG)	NL	1991-2008, FU: 2009, 15-75 yrs	274 (NSCLC)	4				X		1,3,KM	X			X	X	X	X	X[h]	7
USA																			
(Chirikos et al. 1984), PBC(REG)	USA	1977-1981, FU: NA, Age: NA	NA[9]		2	2				1,3,KM			X			X			8
(Clement-Duchene et al. 2016), PCo	USA	2003-2005, FU: 2012, all ages	3410	3	4			X						X	X	X	X[10]	X[i]	8
(Herndon et al. 2008), CT	USA	1988-2001[11], FU:2005, all ages	1577	5				X	X	KM	X								1

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				Outcome						Adjustment[4]					QS
										Survival									
				Education	Income	Occupation	Index	HR	Median Year		OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
Asia																			
(Yeole and Kumar 2004), PBC (REG)	India	1987-1991, FU: until 1996, all ages	1995	4				X	5			X		X		X		X[j]	8
(Yeole 2005), PBC (REG)	India	1992-1994, FU: until 1999, all ages	1230	4				X	5		X			X		X		X[k]	8
(Fujino 2007a), CoS	Japan	1988-1990[12], FU: 2003, 40-79 yrs	1098	3				X						X	X			X[l]	5
(Fujino 2007b), CoS	Japan	1988-1990[12], FU: 2003, 40-79 yrs	NA			6,3,4[5]		X						X	X			X[l]	5
(Yim et al. 2012), RCo	Korea	2000, FU: ≤ 48 mths, all ages	261	3				X	3,KM		X		X	X	X	X		X[m]	7
(Chang et al. 2012), PGB (INS)	Taiwan	2002, FU: 5 years, all ages	4698	6				X	5,KM		X			X	X	X		X[n]	8

Abbreviations: CSS = Cause-specific survival; CoS = Cohort study; CT = Data from clinical trials; FU = Follow-up length; HR = Hazard ratio; mths = months; INS = Insurance; KM = Study provided Kaplan-Meier-Curve(s) or other survival curves stratified by SES; NA = Not available; NL = The Netherlands; NSCLC = Non-small cell lung cancer; OS = Overall survival; PBC = Population-based cohort; PCo = Prospective cohort; QS = Quality score; RCo = Retrospective cohort; REG = Registry; RS =Relative survival; SEER = Surveillance, Epidemiology, and End Results Program; SES = Socioeconomic status; Yrs = years of age; [1]Data sources for survival data; [2]Only lung cancer patients; [3]Numbers indicate number of groups, excluding unknown/missing; [4]Adjustment by stratification and standardization was also considered; if both model and survival rates were calculated, only model adjustments are reported; [5]Study assessed two (three) indicators for occupation; [6]Sample size: 114000 (all cancers); [7]Combination of education and occupation; [8]Study reported relative excess risk; [9]Sample size: 1180 (all cancers, only men); [10]Study included only non-smokers; [11]Enrollment dates; [12]Study start; [a]Comorbidities, first-line treatment, performance status, period; [b]Histologic type/grade, period/year, sub-site; [c]Health services region, radiotherapy, surgery; [d]Histopathology, performance status, treatment; [e]Period; [f]Birth cohort, histology, performance status; [g]Comorbidity, marital status, pattern of care; [h]Alcohol, comorbidities, period, physical activity; [i]Race, comorbidity, insurance, health care setting, histology, surgery, chemotherapy, radiotherapy; [j]Marital status, treatment; [k]Marital status, religion, treatment; [l]Area of study; [m]Family history, out-patient-visits per month, performance status; [n]Comorbidities, hospital characteristics, treatment modality

Table 7 Characteristics of included studies with aggregated measurements of socioeconomic status.

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				SES Level[4]	Outcome						Adjustment[5]					QS
											Survival									
				Education	Income	Occupation	Index		HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
Europe																				
(Chouaid et al. 2017), RCo	France	2011, FU: 2013, all ages	41115				4	Com-mune	X		1,2	X			X	X			X[a]	7
(Jansen et al. 2014), PBC (REG)	Germany	1997-2006, FU: 2006, NA	105688				5	District			5		X[6]		X		X			8
(Aarts et al. 2015), PBC (REG)	NL	2001-2012, FU: 2014, all ages	5428 NSCLC stage IV				4	PC	X	X	1	X			X	X			X[b]	8
(Louwman et al. 2010), PBC (REG)	NL	1997-2006, FU: NA, all ages	12945				3	PC	X		1	X			X	X			X[c]	8
(Schrijvers et al. 1995a), PBC (REG)	NL	1980-1989, FU: 1991, all ages	4591				5	PC	X		5		X		X		X		X[d]	8
(Pollock and Vickers 1997), PBC (REG)	England	1987-1992, FU: 1992, 40-99 yrs	22842				10	ED			5,KM		X		X	X				8
(Schrijvers et al. 1995b), PBC (REG)	England	1980-1989, FU: 1992, 30-99 yrs	40279				5	ED	X		5		X		X	X	X		X[e]	8
(Berglund et al. 2012), PBC (REG)	England	2006-2008, FU: 2009, 0-80+ yrs	15582		5			LSOA	X		3,KM	X			X	X	X		X[f]	8
(Nur et al. 2015), PBC (REG)	England	2001-2005, FU: 2011, 15-99 yrs	145532				5	LSOA			1,5,10 KM		X[6]		X	X				8
(Rachet et al. 2010), PBC (REG)	England	1996-2006, FU: 2007, 15-99 yrs	303422				5	LSOA					X[7]		X	X			X[g]	8
(Riaz et al. 2011), PBC	England	2003-2007, FU: 2008, all ages	150939		5			LSOA			1	X				X			X[h]	7
(Rich et al. 2011), PBC	England	2004-2008 (data entry), FU: 2008, all ages	60059				5	LSOA	X						X	X	X		X[i]	8
(Coleman et al. 2001), PBC (REG)	England/ Wales	1971-1990, FU: 1995, all ages	144604				5	ED			1,5		X		X					7
(Rachet et al. 2008), PBC (REG)	England/ Wales	1986-1999, FU: 2001, 15-99 yrs	392000		5			LSOA			5					X			X[g]	6

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				SES Level[4]	Outcome						Adjustment[5]					QS
									Survival											
				Education	Income	Occupation	Index		HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
(Sloggett et al. 2007), PBC	England/ Wales	1981-1997, FU: 2000, ≥45 yrs	4271			6	5	Ward/ IND					X[6]		X	X			X[j]	8
(Coleman et al. 2004), PBC (REG)	England/ Wales	1986-1990, FU: 2001, 15-99 yrs	107317				5	Electoral ward					X[7]			X				7
(Campbell et al. 2000), PBC (REG)	Scotland	1991-1995, FU: 1995, all ages	19449				5	OA			1	X								8
(Shack et al. 2007), PBC (REG)	Scotland	1986-2000, FU: 2004, 15-99 yrs	20851				5	Postcode sector			5		X		X	X				8
(Iyen-Omofoman et al. 2011) 2011, PCo	UK	2000-2009, FU: 2009, all ages	12135				5	OA	X	X	1,5	X								6
(O'Dowd et al. 2015), PCo	UK	2000-2013, FU: 3 mths, ≥ 30 yrs	20142				5	OA			1,3 mth	X								6
(Cheyne et al. 2013), RCo	UK	2008-2010, FU: NA, 31-97 yrs	1432			5	5	LSOA		X	1	X								4
(Ellis et al. 2014), PBC (REG)	UK	2001-2005, FU: 2009, ≥35 yrs	145206				5	LSOA			1,5		X[7]			X		X		8
(Forrest et al. 2015), PBC (REG)	UK	2006-2009, FU: ≥ 2 yrs, all ages	22967		5			LSOA			2	X								8
(Jack et al. 2006), PBC (REG)	UK	1998, FU:NA, all ages	695				5	Ward			1	X								8
(Vercelli et al. 2006), PBC (REG)	Europe	1990-1994, FU: ≥ 5 yrs, 65-84 yrs	657541		X[8]			Country			5		X			X				7
(Evans and Pritchard 2000), PBC	Europe/USA	Europe: 1983-1985, USA: 1983-1989, FU: 1995,0-84 yrs	10 countries		X[8]			Country			5		X		X	X				8
Canada/USA																				
(Mackillop et al. 1997), PBC (REG)	Canada	1982-1991, FU: NA, Age: NA	357530 all cancers		5			Postal code	X		5,KM			X	X	X			X[k]	8
(Booth et al. 2010), PBC (REG)	Canada	2003-2007, FU: ≥ 1 year, Age: NA	12276 NSCLC		5			Com-munity	X		3,5	X		X	X		X			8
(Dabbikeh et al. 2017), PBC (REG)	Canada	1993-2009, FU: 2013, all ages	122889		5		5	EA/DA	X		5			X	X	X				8
(Boyd et al. 1999), PBC (REG/SEER)	Canada/USA	1987-1992, FU: 1994, ≥20 yrs	NA[9]		5			USA: CeT, Canada: EA	X		5,KM			X	X	X			X[g]	8

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				SES Level[4]	Outcome						Adjustment[5]					QS
											Survival									
				Education	Income	Occupation	Index		HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
(Gorey et al. 1997), PBC (REG/SEER)	Canada/USA	Canada:1986-1992, FU: 1993, ≥25 yrs USA:1984, FU: 1991, ≥25 yrs	Canada: 58202 USA: 76055		3			CeT			1,5[10]					X				8
(Zhang-Salomons et al. 2006), PBC (REG/SEER)	Canada/USA	Canada:1989-1993, FU: 1998, ≥25 yrs USA: 1988-1992, FU: 1997, ≥25 yrs	Canada: 8209, USA: 15261		5			CeT	X		5			X	X	X				8
(Gomez et al. 2016), PBC (REG)	USA	2000-2010, FU: 2012, all ages	3832 Chinese ethnicity				5	CBG	X	X		X			X	X	X		X[l]	8
(Hastert et al. 2015), PBC (SEER)	USA	2000-2002, FU: 2010, 50-76 yrs	52186	4	5		5	CBG	X						X	X			X[m]	8
(Lara et al. 2017), PBC (REG)	USA	1998-2012, FU: 2013, all ages	22863 SCLC				2	CBG	X					X	X	X	X		X[n]	8
(Ou et al. 2007), PBC (REG)	USA	1989-2003, FU: median 53 mths, all ages	19702[14] NSCLC, stage I				5	CBG	X						X	X	X		X[N]	8
(Ou et al. 2008), PBC (REG)	USA	1989-2003, FU: median 53 mths, all ages	19702[14] NSCLC, stage I				5	CBG	X	X	5,KM	X			X	X			X[o]	8
(Ou et al. 2009), RCo	USA	1991-2005, FU: ≥ 77 mths, all ages	3428 ED-SCLC				5	CBG	X	X	1,2	X			X	X		X	X[p]	7
(Caposole et al. 2014), PBC (REG)	USA	1998-2012, FU:>12 yrs, all ages	3531 NSCLC		4			CeT		X		X								6
(Erhunmwunsee et al. 2012), PBC (REG)	USA	1995-2007, FU: ≥ 2 yrs, 20-105 yrs	4820 NSCLC	2	2			CeT		X	6,KM			X						5

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				SES Level[4]	Outcome						Adjustment[5]					QS
										Survival											
				Education	Income	Occupation	Index		HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
(Greenwald et al. 1994), PBC (REG)	USA	1980-1982, FU: 1987, Mean age 67.6 yrs	78 (NSCLC, stage II)		X			Multi-level (CeT+ IND)	X						X	X				8
(Greenwald et al. 1998), PBC (SEER)	USA	1978-1982, FU: ≥ 10 yrs, ≤75 yrs	5132 NSCLC		10			CeT	X		5	X			X	X			X[q]	8
(Johnson et al. 2014), PBC (REG)	USA	2000-2009, FU: 2011, 50-85 yrs	32711 NSCLC	4	4			CeT	X			X			X	X	X		X[r]	8
(Johnson et al. 2016), PBC (REG)	USA	2000-2009, FU: 2012, 30-85 yrs	8322 early stage NSCLC	4	4			CeT	X						X	X			X[s]	8
(Lara et al. 2014), PBC (REG)	USA	1998-2009, FU: 2011, all ages	114451 NSCLC				3	CeT	X	X				X	X	X	X		X[t]	8
(Lipworth et al. 1970), PBC (REG)	USA	1959-1963, FU: 3 yrs, all ages	246		2			CeT			1,3		X			X				5
(Niu et al. 2010), PBC (REG)	USA	1986-1999, FU: 2004, all ages	64206		4			CeT	X		5			X	X	X	X		X[u]	8
(Shugarman et al. 2008), PBC (SEER)	USA	1995-1999, FU: NA, ≥ 65 yrs	26073		3			CeT	X						X	X	X		X[v]	7
(Tannenbaum et al. 2014), PBC (REG)	USA	1996-2007, FU: ≥ 3 yrs, 18-104 yrs	98541 NSCLC		4			CeT	X	X	1,3,5 KM	X				X	X	X	X[w]	8
(Yang et al. 2010), PBC (REG)	USA	1998-2002, FU: 2006, all ages	97046		4			CeT	X	X	KM	X			X	X	X	X	X[x]	8
(Yu et al. 2014), PBC (SEER)	USA	2000-2002, FU: ≥ 5 yrs, Age: NA	97046				5	CeT						X						7
(Khullar et al. 2015), PBC (NCDB)	USA	2003-2006, FU: NA, Mean 66.0 yrs ± SD 10.33 yrs	92929 NSCLC	4	4			Zip code	X		KM	X			X	X	X		X[y]	8
(McMillan et al. 2017), PBC (NCDB)	USA	2004-2012, FU: 2013, all ages	14154 NSCLC, stage III		2			Zip code	X			X			X	X			X[z]	8
(Melvan et al. 2015), PBC (NCDB)	USA	2003-2011 (resection date), FU: 30 days, ≥ 60 yrs	215645 NSCLC	4	4			Zip code			30day	X								6

Paper, Data source[1]	Country	Years of diagnosis, Follow-up length, Age (range)	Sample size[2]	SES indicator(s)[3]				SES Level[4]	Outcome						Adjustment[5]					QS
										Survival											
				Education	Income	Occupation	Index		HR	Median	Year	OS	RS	CSS	Age	Sex	Stage	Smoking	Other	
(Wen and Christakis 2005), PBC (REG)	USA	1993, FU: 1999, all ages	NA				X[11]	Zip code	X					X						6
(Wang et al. 2017a), PBC (SEER)	USA	1983-2012, FU: NA, 30-75+ yrs	293471 NSCLC		3			County	X		1		X		X	X			X[u]	8
(Wang et al. 2017b), PBC (SEER)	USA	1983-2012, FU: NA, all ages	56220 SCLC		3			County	X		1,2,3,5		X		X	X			X[u]	8
Australia/New Zealand																				
(Bonett et al. 1984), PBC (REG)	Australia	1977-1982, FU: 1983, all ages	2934		X			CD	X					X						8
(Hall et al. 2004), PBC	Australia	1982-1996, FU: ≥ 5 yrs, all ages	9080				5	CD	X		5	X			X	X			X[A]	8
(Tervonen et al. 2017), PBC (REG)	Australia	2000-2008, FU: 2008, all ages	26415				5	CD/SLA	X						X	X	X		X[B]	8
(Currow et al. 2014), PBC (REG)	Australia	2003-2007, FU: 2008, all ages	3040 NSCLC				5	POA	X						X	X			X[D]	8
(Denton et al. 2017), PCo	Australia	2001-2014 (case discussion), FU: NA, Mean age 68 ± 11 (SD) yrs	2369				5	POA	X		5	X			X	X	X		X[E]	7
(Hui et al. 2005), PBC (REG)	Australia	1996, FU: ≥ 4 yrs, 32-91 yrs	526				5	POA		X	KM	X	X							6
(Stanbury et al. 2016a), PBC (REG)	Australia	1991-2008, FU: 2008, 15-89 yrs	33942				5	LGA			5		X[6]		X	X	X		X[F]	8
(Yu et al. 2008), PBC (REG)	Australia	1992-2000, FU: 2001, 15-89 yrs	15251				5	LGA			5		X[6]		X	X	X		X[F]	8
(Jeffreys et al. 2009), PBC (REG)	NZ	1994-2003, FU: 2004, 15-99 yrs	13643				4	MB					X[7]		X					7
(Sutherland and Aitken 2008), RCo	NZ	1997-1999, FU: ≥ 5 yrs,27-92yrs	102				10	MB			X[12]	X								4
(Haynes et al. 2008), PBC	NZ	1994-2001, FU: 2004, Mean age 69 yrs	12420				4	CAU	X						X	X	X		X[G]	8
Asia																				
(Ito et al. 2014), PBC (REG)	Japan	1993-2004, FU: ≥ 5 yrs,Age:NA	39621				5	Cho-Aza			1,5		X[13]			X			X[H]	7
(Kwak and Kim 2017), PBC (REG)	Korea	2010-2011, FU: 2014, all ages	1426				4	Dong	X		1,3,5	X			X	X	X	X	X[L]	8
(Kwak 2017), PBC (REG)	Korea	2000-2011, FU: 2013, all ages	13801				4	Dong	X	X	1,2,3 KM	X			X	X				8

Abbreviations: BMI = Body mass index; CAU = Census Area Unit; CBG = Census block group; CD = Census Collection District; CeT = Census tract; CSS = Cause-specific survival; DA = Dissemination area; EA = Enumeration area; ED = Enumeration district; ED-SCLC = Extensive disease small-cell lung cancer; FU = Follow-up length; HR = Hazard ratio; IND = Individual; IQR = Inter quartile range; KM = Study provided Kaplan-Meier-Curve(s) or other survival curves stratified by SES; LGA = Local Government Area; LSOA = Lower Super Output Area; MB = Meshblock; mth(s) = month(s); NA = Not available; NCDB = National Cancer Data Base (American Cancer Society); NL = The Netherlands; NSCLC = Non-small cell lung cancer; NZ = New Zealand; OA = Output area; OS = Overall survival; PBC = Population-based cohort; PC = Postal code; PCo = Prospective cohort; POA = Postal code area; QS = Quality score; RCo = Retrospective cohort; REG = Registry; RS =Relative survival; SCLC = Small-cell lung cancer; SEER = Surveillance, Epidemiology, and End Results Program; SES = Socioeconomic status; SLA = Statistical Local Area; UK = United Kingdom; wks = Weeks; yrs = Years of age; [1]Data sources for survival data; [2]Only lung cancer patients; [3]Numbers indicate number of groups, excluding unknown/missing; [4]Indicates abbreviated name of area-level; [5] Adjustment by stratification and standardization was also considered; if both model and survival rates were calculated, only model adjustments are reported; [6]Study reported relative excess risk; [7]Study reported deprivation gap; [8]Rank order of % Gross domestic product expenditure on health; [9]Sample size for all cancers: USA n = 486327, Canada n = 187650; [10]Study reported survival rate ratios; [11]SES index has been measured on a continuous scale; [12]Survival rate: 6 weeks, 3 and 6 months, 1, 2, and 5 years, according to correspondence with author; [13]Study reported net survival; [14]Studies included same patient population; [a]Comorbidities, population density; [b]Chemotherapy, comorbidity, grade, histology, location of metastasis, period; [c]Presence of concomitant diseases; [d]Follow-up period, histology, treatment; [e]Follow-up period, period of diagnosis; [f]Comorbidity, resection, radiotherapy, chemotherapy; [g]Year of diagnosis; [h]Urban/rural; [i]Histology, performance status; [j]Marital status, north/south geographic zone, period of diagnosis, year of follow-up; [k]Cancer center catchment area, year of diagnosis; [l]Cancer center, chemotherapy, health insurance, histologic subtype, marital status, nativity, neighborhood ethnic enclave, radiation, surgery type, urban/rural, year of diagnosis; [m]Race/ethnicity, marital status; [n]Race, treatment, urban/rural, year of diagnosis; [o]Chemotherapy, ethnic origin, histologic grade, histology, marital status, radiation, surgery, tumor lobar location; [p]Chemotherapy, ethnicity, marital status, radiation, surgery; [q]Race, surgery; [r]Race, treatment, tumor grade; [s]Elderly concentration, place of residence, race, racial segregation, random census tract effect, surgery, tumor grade; [t]Histology, race, treatment, urban/rural, year of diagnosis; [u]Race; [v]Urban/rural, race, marital status, Medicaid, comorbidity, year of diagnosis, treatment, English speaking, health professional shortage area, health care provider supply characteristics; [w]Comorbidities, geographic location, grade, histological type, hospital volume, insurance status, lymph node status, marital status, race/ethnicity, teaching hospital, treatment; [x]Comorbidities, grade, insurance, lymph node status, race/ethnicity, tumor size, histology, surgery, radiation, chemotherapy; [y]Comorbidity, facility type, grade, histology, insurance, lymph nodes, primary tumor site, race, radiation before surgery, surgery, urban/rural, year of diagnosis; [z]Comorbidity, distance between residence and hospital, facility type, grade, histology, insurance, race , TN classification, tumor location, tumor size, chemotherapy, radiation fractions, radiation treatment time; [A]Calendar period, comorbidity, histology, indigenous status, insurance status, location/status of hospital, marital status, remoteness, surgical status; [B]Country of birth, remoteness, year of diagnosis; [D]Comorbidity, country of birth, histology, insurance status, local health districts, lung location, remoteness, resection; [E]Place of residence; [F]Follow-up year; [G]Ethnic group, travel to primary care, travel to cancer center; [H]Period of diagnosis; [L]BMI, diagnosis path (by regular checkup, by chance, by symptom), drinking; [N]Chemotherapy, ethnic origin, histologic grade, histology, radiation, surgery, tumor lobar location, tumor size, period of diagnosis

3.1.2 Association of individual SES and survival – modelling results

Detailed modelling results for all studies with individual measures are displayed in Table A1, Appendix. The majority of studies adjusted for age, gender, stage, and treatment. Three studies adjusted for smoking (Aarts et al. 2013; Berglund et al. 2010; Clement-Duchene et al. 2016) (Table 6). Overall, there was no consistent difference in survival between studies with different levels of adjustment for prognostic factors (Figure 8).

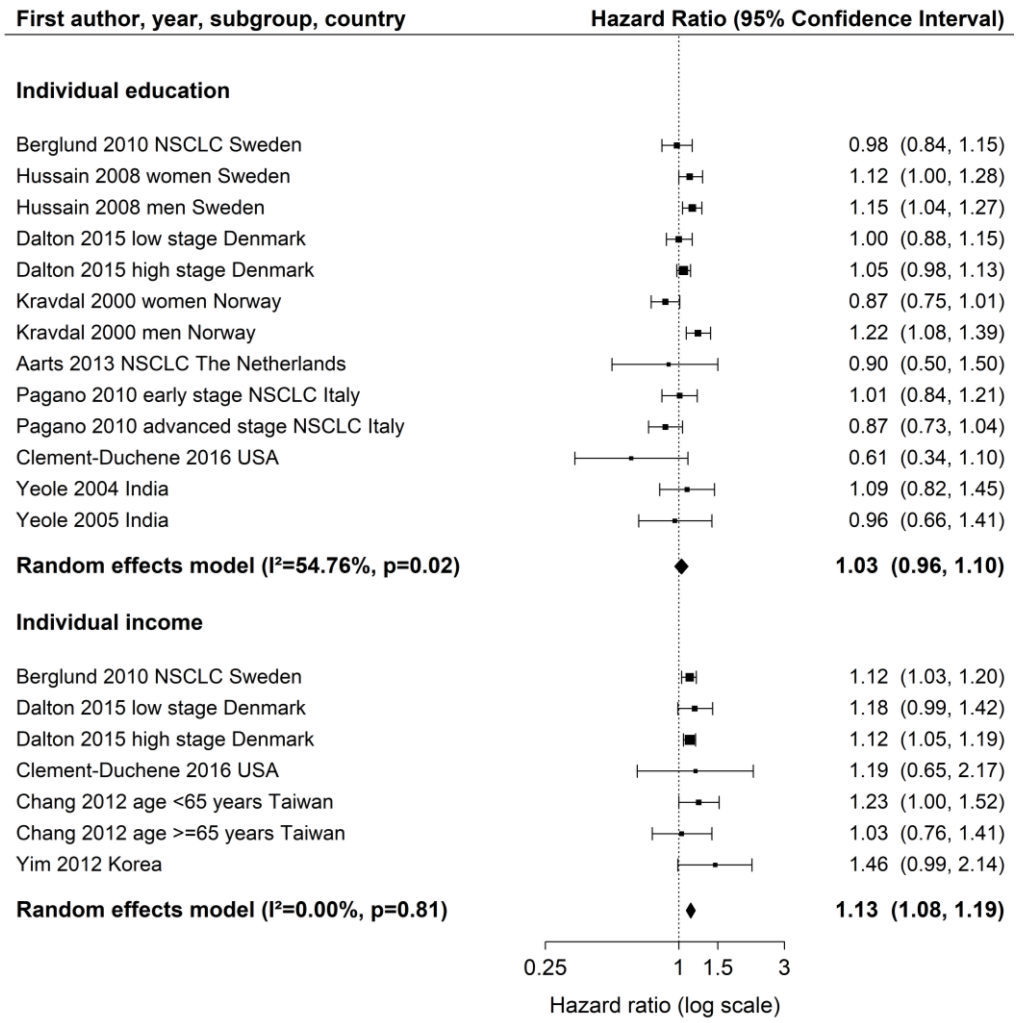

Figure 8 Meta-analyses of studies on the association of individual education / income (reference: high income/education) and survival after lung cancer. Abbreviation: NSCLC, non-small cell lung cancer. Kravdal 2000: highest educational group, men = 17+ years, women = 13-17+ years. Chang 2012: high income category = high individual AND high neighborhood income (reference), low income category = low individual AND low neighborhood income.

For individual education (Figure 8), nine studies (Aarts et al. 2013; Berglund et al. 2010; Clement-Duchene et al. 2016; Dalton et al. 2015; Hussain et al. 2008; Kravdal 2000; Pagano et al. 2010; Yeole 2005; Yeole and Kumar 2004) were included in the meta-analysis. The summary estimate from the random effects model revealed no association between education and lung

cancer survival (HR 1.03, 95 % CI 0.96-1.10). The results of these studies were rather heterogeneous (I^2 = 54.76 %, p = 0.02). A stratified meta-analysis by stage at diagnosis was possible with three studies (Berglund et al. 2010; Dalton et al. 2015; Pagano et al. 2010), but no significant associations were observed (early stage: HR 1.03, 95 % CI 0.92-1.15; late stage: HR 0.94, 95 % CI 0.81-1.08; Figure A1, Appendix). Stratified meta-analyses were conducted for studies that included stage, smoking or treatment in Cox models (Figures A2, A3, and A4, Appendix). These analyses showed smaller effect estimates in studies that adjusted for stage (stage adjustment: HR 1.00, 95 % CI 0.92-1.08; no stage adjustment: HR 1.14, 95 % CI 1.05-1.23, Figure A2, Appendix) or smoking status (smoking adjustment: HR 0.91, 95 % CI 0.72-1.14; no smoking adjustment: HR 1.04, 95 % CI 0.97-1.12, Figure A3, Appendix), but CIs were wide and overlapping. Stratified meta-analyses by studies that included treatment in Cox models did not suggest a difference in effect estimates (Figure A4, Appendix). Three studies (Di Maio et al. 2012; Fujino 2007a; Herndon et al. 2008) were not included in the meta-analysis because of low scores for quality assessment. A sensitivity analysis was conducted by including these three studies into the meta-analysis. Results were similar to the main analysis (HR 1.05, 95 % CI 0.99-1.12, Figure A5, Appendix).

For individual income (Figure 8), five studies (Berglund et al. 2010; Chang et al. 2012; Clement-Duchene et al. 2016; Dalton et al. 2015; Yim et al. 2012) were included in the meta-analysis showing a lower survival after lung cancer diagnosis for patients in the lowest income group compared to patients in the highest income group (HR 1.13, 95 % CI: 1.08-1.19). The studies were homogeneous (I^2 = 0.00 %, p = 0.81). All studies included in the meta-analysis of individual income adjusted for stage (Table 6). A stratified meta-analysis by smoking adjustment gave similar estimates as for the main analysis (smoking adjustment: HR 1.12, 95 % CI 1.03-1.22; no smoking adjustment: HR 1.14, 95 % CI 1.07-1.20, Figure A6, Appendix). Exclusion of one study not adjusting for treatment (Yim et al. 2012) resulted in a marginal change of estimate (HR 1.13, 95 % CI 1.08-1.18, Figure A7, Appendix). One study was not included in the meta-analysis because of reporting on a continuous scale (Greenwald et al. 1994) and indicated an association between higher income and lower risk of death after lung cancer diagnosis (Table A1, Appendix).

Individual occupation was investigated in three studies (Berglund et al. 2010; Fujino 2007b; Kravdal 2000) (Table A1, Appendix). As the measures were very heterogeneous, a meta-

analysis was not possible. In summary, no lower survival with decreasing SES was reported for occupational groups. Fujino (Fujino 2007b) conducted analyses stratified by gender and reported a higher risk of dying after lung cancer diagnosis for housewives (women) and unemployed women compared to employed women but he did not consider other confounding factors besides gender. Kravdal (Kravdal 2000) stratified occupational groups by education and reported for the low educational group a lower risk of death in non-manual occupations and a lower survival in farmers compared to manual occupations within the same educational group (Table A1, Appendix). High-level non-manual occupations with medium education had a lower risk compared to low educated manual occupations (Kravdal 2000).

No study reported HRs for the association between an individually measured SES index and lung cancer survival (Table 6).

3.1.3 Association of area-based SES and survival – modelling results

Characteristics of SES exposure of most studies on area-based SES measurements were too heterogeneous to conduct meta-analyses. However, for studies reporting HRs for SES group comparisons, the HRs for low SES versus high SES (reference) are shown in Figure 9 (education), 10 (income) and 11 (index), sorted by region and area-level (small to large). Figure 12 additionally displays a meta-analysis for studies on area-based income from the US. Ten studies were not displayed in figures because they did not report CIs (Dabbikeh et al. 2017; Haynes et al. 2008; Shugarman et al. 2008; Zhang-Salomons et al. 2006), did not show results (Bonett et al. 1984), assessed SES on a continuous scale (Greenwald et al. 1994; Greenwald et al. 1998; Ou et al. 2007; Wen and Christakis 2005) or did not use low or high SES as reference category (Boyd et al. 1999). Results of all studies are reported in detail in Table A2, Appendix.

Three studies (Johnson et al. 2014; Johnson et al. 2016; Khullar et al. 2015) investigated area-based measurements of education and all reported a lower survival after lung cancer diagnosis in areas with the lowest education levels (Figure 9, Table A2, Appendix). All studies adjusted for age, sex and stage at diagnosis and included patients diagnosed with NSCLC residing in the USA. The extent of the association did not depend on the size of area-level (Figure 9). Results of area-based studies were more homogeneous and reported stronger associations compared to studies investigating individual education.

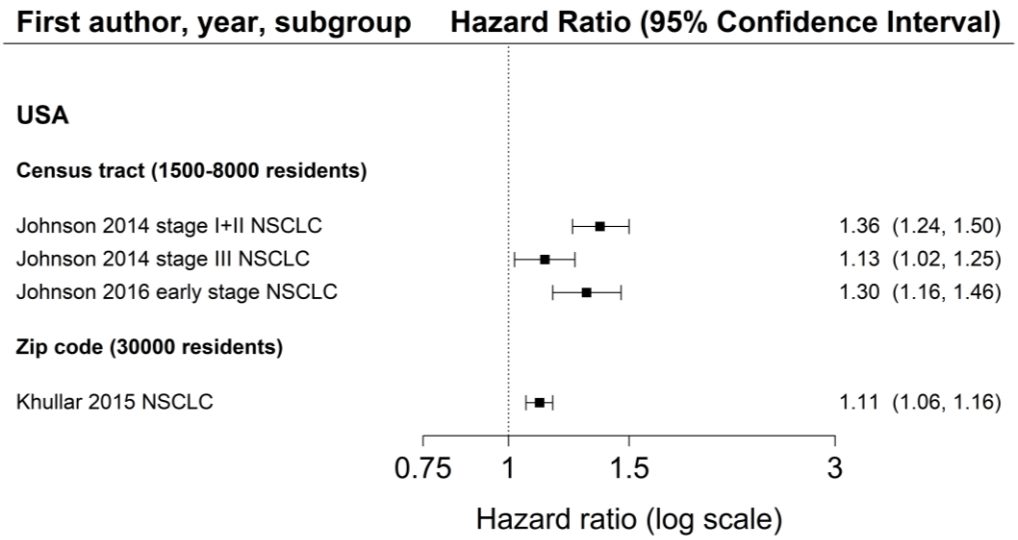

Figure 9 Association of area-based education (reference: high education) and survival after lung cancer. Order: small to large area level. NSCLC = non-small cell lung cancer.

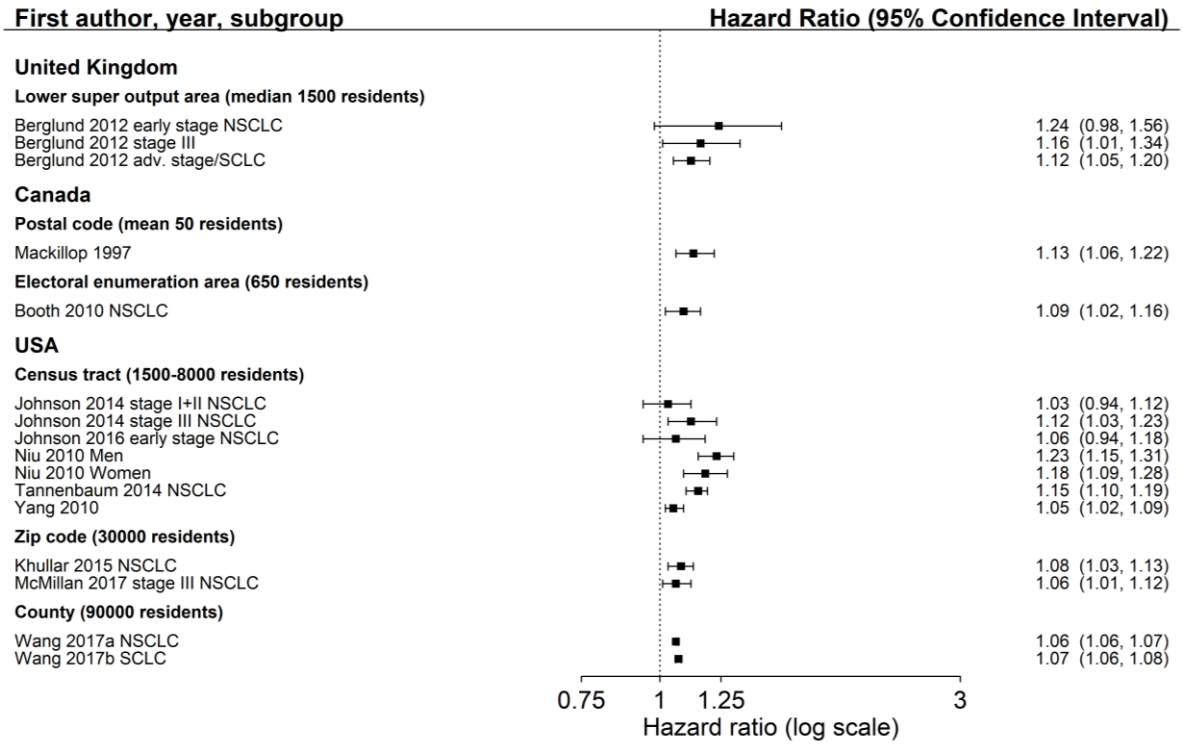

Figure 10 Association of area-based income (reference: high income) and survival after lung cancer. Order: small to large area level. NSCLC = non-small cell lung cancer; SCLC = small cell lung cancer.

The association between area-based income and lung cancer survival was investigated in 19 studies (Berglund et al. 2012; Bonett et al. 1984; Booth et al. 2010; Boyd et al. 1999; Dabbikeh et al. 2017; Greenwald et al. 1994; Greenwald et al. 1998; Johnson et al. 2014; Johnson et al. 2016; Khullar et al. 2015; Mackillop et al. 1997; McMillan et al. 2017; Niu et al. 2010; Shugarman et al. 2008; Tannenbaum et al. 2014; Wang et al. 2017a; Wang et al. 2017b; Yang

et al. 2010; Zhang-Salomons et al. 2006). Twelve studies displayed in Figure 10 in general show a lower survival for the lowest income group compared to the highest group (range: HR 1.03-1.24, Figure 10). Estimates of seven studies (Berglund et al. 2012; Johnson et al. 2014; Johnson et al. 2016; Khullar et al. 2015; Niu et al. 2010; Tannenbaum et al. 2014; Yang et al. 2017) adjusting for stage at diagnosis were similar to estimates of studies not adjusting for stage (Table 7, Figure 10). The meta-analyses of six US studies (Johnson et al. 2014; Khullar et al. 2015; Niu et al. 2010; Tannenbaum et al. 2014; Wang et al. 2017a; Wang et al. 2017b) revealed a slightly larger summary estimate for the smaller area-level of CeTs (HR 1.15, 95 % CI 1.09-1.21, Figure 12) than for the two larger area-levels zip code and county (zip code: HR 1.08, 95 % CI 1.03-1.13; county: HR 1.06, 95 % CI 1.06-1.07, Figure 12). However, not all of these studies adjusted for stage, which hampers their comparability. Two studies had been excluded from this meta-analysis due to overlapping study populations. The study by McMillan et al. (McMillan et al. 2017) has overlapping population with the study by Khullar et al. (Khullar et al. 2015). It was decided to include Khullar et al. (Khullar et al. 2015) in the meta-analysis as all stages were analyzed compared to McMillan et al. (McMillan et al. 2017) which included solely patients diagnosed with stage III. The study by Yang et al. (Yang et al. 2010) was excluded because there is overlapping population with the study by Tannenbaum et al. (Tannenbaum et al. 2014). Although Tannenbaum et al. (Tannenbaum et al. 2014) included solely patients diagnosed with NSCLC, they included a longer period of diagnosis compared to Yang et al. (Yang et al. 2010).

The majority of studies reported lower survival in lower income areas (Table A2 Appendix). Twenty-two studies reported HRs on the association between an area-based SES index measure and lung cancer survival (Table A2, Appendix). Group comparisons of eighteen studies showed significant associations between lower income areas and a lower survival after lung cancer diagnosis in ten studies (Chouaid et al. 2017; Gomez et al. 2016; Hastert et al. 2015; Kwak 2017; Lara et al. 2017; Lara et al. 2014; O'Dowd et al. 2015; Ou et al. 2008; Schrijvers et al. 1995a; Tervonen et al. 2017), with a range of HR 1.05-2.21 (Figure 11). Nine studies (Denton et al. 2017; Gomez et al. 2016; Kwak and Kim 2017; Lara et al. 2017; Lara et al. 2014; Ou et al. 2007; Rich et al. 2011; Schrijvers et al. 1995b; Tervonen et al. 2017) adjusted for stage at diagnosis (Table 7). Notably, no study reported an HR below 1.00. Within-country comparisons did not reveal a tendency for larger or smaller estimates depending on the size of the area-level (Figure 11).

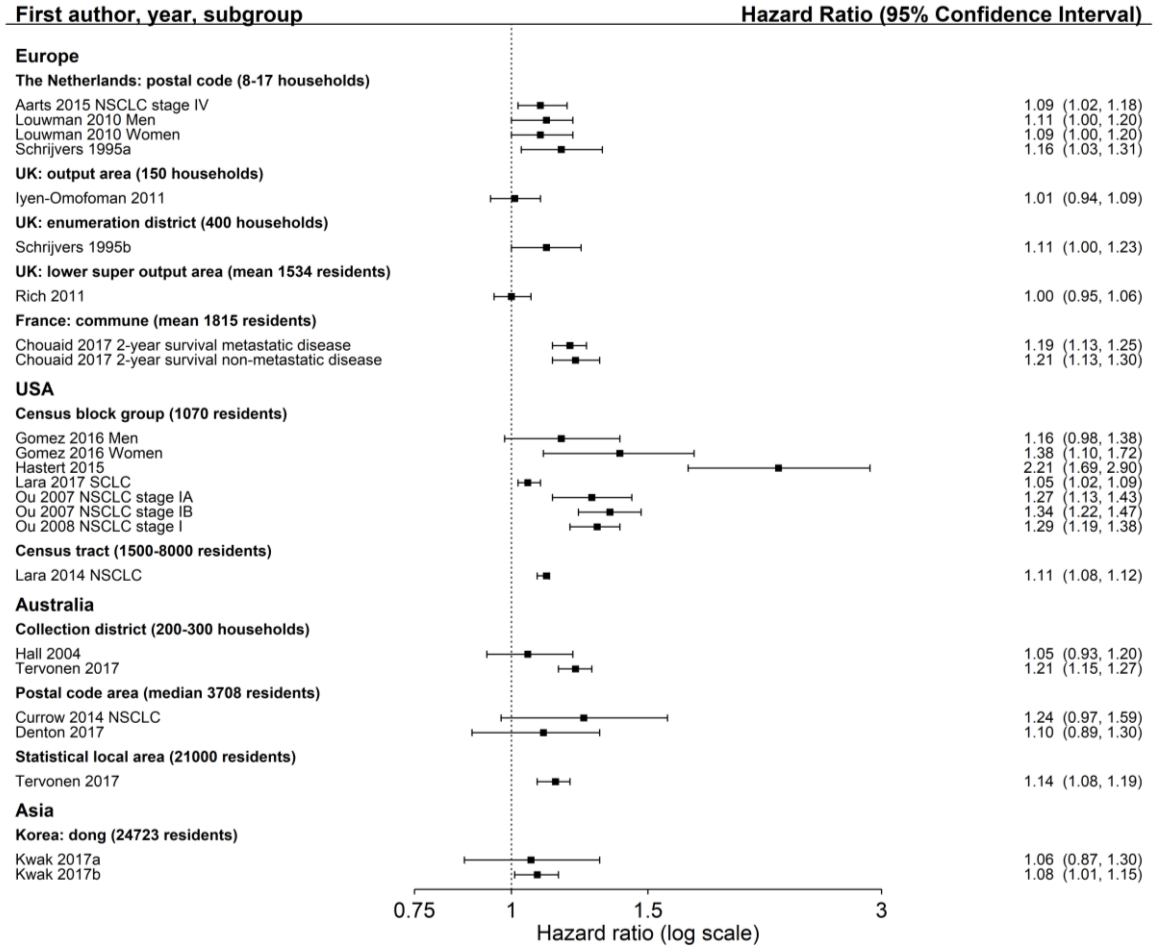

Figure 11 Association of area-based index measures (reference: high socioeconomic group) and survival after lung cancer. Order: region and small to large area level. NSCLC = non-small cell lung cancer; SCLC = small cell lung cancer; UK = United Kingdom.

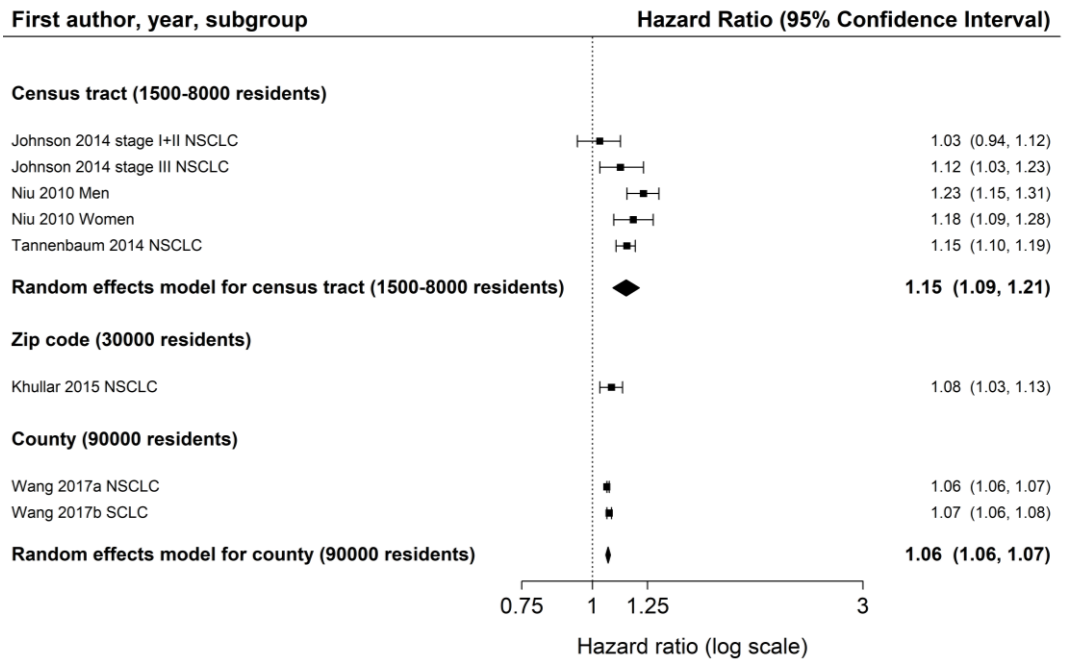

Figure 12 Meta-analysis of studies from the United States on the association of area-based income (reference: high income) and survival after lung cancer. Order: small to large area level. NSCLC = non-small cell lung cancer; SCLC = small cell lung cancer.

The majority of studies adjusted for age, gender and stage. Two income studies (Tannenbaum et al. 2014; Yang et al. 2010) and two SES index studies (Kwak and Kim 2017; Ou et al. 2009) included smoking status in their models (Table 7). The latter two studies reported slightly lower estimates than studies without adjustment for smoking (Table A2, Appendix).

3.1.4 Combined effects of individual and area-based SES – modelling results

Two studies investigated both individual and area-based SES (Greenwald et al. 1994; Hastert et al. 2015). However, only one study investigated directly combined effects of individual and area-based income (Greenwald et al. 1994). These analyses are based on a population size of N=78 patients with stage II NSCLC and showed a significantly lower survival only for higher individual income. In the combined model, the area-level variable did not add any explanatory power to the model including individual income (Greenwald et al. 1994) (Table A2, Appendix). The other study analyzed area-based SES with adjustment for individual SES in the Cox model (Hastert et al. 2015). The study reported a significant association between lower area-level SES and lung cancer survival in both models with and without adjustment for individual SES (Hastert et al. 2015). The estimate of the model including individual SES adjustment was considerably smaller (including individual SES: HR 1.43, 95 % CI 1.07-1.91; without individual SES: HR 2.21, 95 % CI 1.69-2.90).

3.1.5 SES and survival time, survival rate and other survival measures

Overall, 67 studies reported median survival time or survival rates after lung cancer stratified by SES. Fifteen and 52 studies used an individual or area-based SES measure, respectively. Nine individual and 45 area-based SES studies reported lower lung cancer survival in lower SES groups. The remaining 6 individual (Aarts et al. 2013; Grivaux et al. 2011; Herndon et al. 2008; Pastorino et al. 1990; Yeole 2005; Yeole and Kumar 2004) and 9 area-based studies (Chouaid et al. 2017; Coleman et al. 2001; Evans and Pritchard 2000; Jeffreys et al. 2009; Kwak and Kim 2017; Rachet et al. 2008; Shack et al. 2007; Vercelli et al. 2006; Yu et al. 2008) reported no difference or no gradient across socioeconomic categories in survival time or survival rates.

One individual study (Skyrud et al. 2016) and four area-based studies (Jansen et al. 2014; Sloggett et al. 2007; Stanbury et al. 2016a; Yu et al. 2008) calculated the RER and indicated a lower risk for higher SES groups. Eight area-based studies (Coleman et al. 2001; Coleman et al. 2004; Ellis et al. 2014; Ito et al. 2014; Jeffreys et al. 2009; Rachet et al. 2010; Rachet et al. 2008;

Shack et al. 2007) used the deprivation gap which indicates the survival difference between the highest and lowest SES group and is mostly used in the UK. All of these studies reported a negative deprivation gap, meaning that the highest SES group has a higher survival rate than the lowest SES group.

3.1.6 Risk of bias

Table A3 (Appendix) displays the risk of bias assessment for included studies according to a modified NOS. Overall, the mean quality scores of individual and area-based studies were rather in line, both ranging from 7-8 out of 8 points. As the majority used data of national or regional cancer registries, many studies scored high within the categories selection and outcome, representing for example adequacy of follow-up or representativeness of study population.

Both funnel plots for the meta-analyses of individual education and income studies did not reveal any asymmetry (Education: Begg's test p = 0.13, Egger's test p = 0.07, Figure A8, Appendix; income: Begg's test p = 0.38, Egger's test p = 0.34, Figure A9, Appendix). The funnel plot of individual education analysis appeared to be cylindrical which might be due to the larger heterogeneity between these studies (Figure 8 and Figure A8, Appendix).

3.2 Overview analysis of data from epidemiological cancer registries in Germany[6]

In total, records of 2,333,547 cases were included in the overview analysis of epidemiological cancer registries (Figure 2, Table 8). Table 8 shows characteristics of the study population according to the area-based socioeconomic deprivation of their municipalities. The proportion of DCO cases was similar across area-based socioeconomic deprivation quintiles. Patients resident in the least deprived municipalities were slightly younger (67 years) and showed a marginally higher proportion of microscopically confirmed cases (97.3 %) compared to all other patients.

For all cancer sites combined, there was a gradient across area-based socioeconomic deprivation quintiles in 5-year age-standardized RS (Table 9, Table 10). This clear survival gradient was also present for stomach, colorectal, and prostate cancer. Compared to the least deprived GIMD quintile (Q1), the most deprived quintile (Q5) had a lower five-year RS for 17 of 25 cancer sites and for all cancer sites combined (RER 1.16, 95 % CI 1.14-1.18). Adjusting for stage at diagnosis attenuated the association for eight out of 17 cancer sites, but increased effect estimates for cancers of the oral cavity, lung, breast, ovary, testis, and bladder.

Table 11 shows subgroup analyses of 5-year RS for female breast, prostate, colorectal, and lung cancer stratified by age group, stage, and sex (where applicable). The association of lower survival in the most deprived group was stronger for younger patients for breast and prostate cancer but comparable across age groups for colorectal and lung cancer. However, after adjustment for stage, the age difference resolved for prostate cancer but became apparent for CRC. In general, adjusting for stage attenuated the associations in prostate and CRC but increased effect estimates for breast cancer. In colorectal and lung cancer, associations were stronger in male patients. Associations were weakest in advanced stage in prostate, colorectal, and lung cancer but not in breast cancer. Restricting the analyses to patients with available stage information attenuated the association in prostate, colorectal, and lung cancer but increased effect estimates in younger breast cancer patients (Table 12).

Table 13 shows RERs estimates for 3-month, 1-year and 5-year conditional on 1-year survival for the most deprived compared to the least deprived quintile adjusted for age and for age and stage. Tables 14, 15, and 16 show the corresponding RS rates. With adjustment for age,

[6]The different parts of this chapter are based on and were presented in the article Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

association strengths weakened continuously from 3-month to 1-year to 5-year conditional on 1-year survival for 16 of 25 cancer sites. For all cancer sites combined, the RER decreased from 1.31 to 1.19 to 1.12. With additional adjustment for stage, this pattern was observed for 14 out of 20 cancer sites with RERs decreasing for all cancers combined from 1.36 to 1.18 to 1.14.

Table 17 compares 5-year RS rates and RER for the most and the least deprived quintiles between the periods 2003-2005 and 2012-2014. The association was slightly attenuated from the earlier to the most recent period for most cancer sites and all cancer sites combined (2003-2005: RER 1.20, 95 % CI 1.18-1.23; 2012-2014: RER 1.16, 95 % CI 1.14-1.18). In Figure 13, differences in 5-year RS rates across GIMD quintiles are shown for lung, breast, colorectal, and prostate cancer for the periods from 2003-2005 to 2012-2014. In general, survival improved from the earliest to the most recent period but survival differences across GIMD quintiles remained.

In sensitivity analyses, associations were attenuated when adjusting for federal state and to a lesser extent when adjusting for East-/West-Germany (Tables 18 and 19). RERs for all cancer sites combined for Q5 vs. Q1 were 1.11 (95 % CI 1.09-1.13) and 1.13 (95 % CI 1.11-1.15) with these adjustments compared to 1.16 (95 % CI 1.14-1.18) without such adjustments. Restricting the trend analysis to registries providing data for all years of diagnosis 1998-2014 slightly decreased effect estimates in 2003-2005 and slightly increased estimates in 2012-2014 for most cancer sites. This resulted in a slight increase rather than decrease of the RER estimate over time for all cancer sites combined which was 1.14 (95 % CI 1.11-1.17) in 2003-2005 and 1.18 (95 % CI 1.15-1.22) in 2012-2014 (Table 20).

Table 8 Number of patients with 25 common forms of cancer according to their area-based socioeconomic deprivation (in quintiles) assigned by their residence at diagnosis

GIMD Quintile	GIMD score, mean (range)	Underlying population in 2006 (million)	Cases diagnosed in 1998-2014[a]	% DCO cases[b]	Cases in the analysis, N (%)[c]	Median age at diagnosis	Microscopically confirmed cases (%)[d]
Q1, least deprived	9 (2-13)	6.33	423,114	9.0	384,883 (16.5)	67	97.3
Q2	15 (13-18)	6.52	494,740	9.8	446,372 (19.1)	68	96.0
Q3	20 (18-24)	6.32	504,691	10.8	450,300 (19.3)	68	95.7
Q4	26 (24-30)	6.42	559,118	9.1	508,430 (21.8)	68	95.7
Q5, most deprived	39 (30-70)	6.37	596,391	8.9	543,562 (23.3)	68	95.7
Total	22 (2-70)	31.95	2,578,054	9.5	2,333,547 (100.0)	68	96.0

[a]Due to different coverage of years of diagnosis across GIMD quintiles, case numbers across GIMD quintiles are not directly comparable; [b]DCO or autopsy only cases among included cancer sites; [c]Exclusions are shown in the flow chart (Figure S2); [d]DCO cases and cases with missing information on confirmation were excluded; Abbreviations: DCO, death certificate only; GIMD, German Index of Multiple Deprivation; N, number.

Table 9 Five-year age-standardized relative survival in 2012-14 by GIMD quintile and cancer site for cancer patients in Germany

			GIMD Quintiles (Q)							
			5-year relative survival rate (standard error)						Relative excess risk for Q5 compared to Q1 (95 % confidence interval)	
Cancer site	ICD-10 code	Number of cases	Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)	Q1-Q5[a]	Adjusted for age	Adjusted for age and stage
Oral	C00-C14	40,971	52.0 (1.1)	52.9 (1.1)	50.2 (1.0)	48.5 (1.0)	46.0 (1.0)	6.0	**1.36 (1.25-1.48)**	**1.45 (1.32-1.59)**
Esophagus	C15	18,629	25.3 (1.2)	23.9 (1.2)	26.1 (1.1)	22.7 (1.1)	21.0 (1.0)	4.3	**1.16 (1.06-1.27)**	1.12 (1.00-1.25)
Stomach	C16	48,850	34.2 (0.8)	34.1 (0.8)	33.9 (0.8)	33.3 (0.7)	30.8 (0.7)	3.4	**1.11 (1.04-1.18)**	**1.11 (1.02-1.20)**
Colon and rectum	C18-C21	190,434	65.7 (0.4)	64.2 (0.4)	63.4 (0.4)	63.0 (0.4)	62.0 (0.4)	3.7	**1.23 (1.18-1.29)**	**1.18 (1.12-1.24)**
Liver	C22	22,069	19.7 (1.1)	18.2 (1.1)	17.5 (1.0)	15.0 (0.9)	15.5 (0.9)	4.2	**1.21 (1.11-1.31)**	1.11 (0.97-1.28)
Gallbladder	C23-C24	14,645	25.4 (1.6)	24.6 (1.6)	22.4 (1.5)	24.7 (1.4)	22.0 (1.4)	3.4	**1.15 (1.04-1.28)**	**1.15 (1.00-1.32)**
Pancreas	C25	42,841	13.3 (0.7)	13.3 (0.7)	11.2 (0.6)	13.1 (0.7)	11.3 (0.6)	2.0	**1.12 (1.06-1.18)**	**1.09 (1.02-1.16)**
Larynx	C32	11,021	65.7 (2.0)	63.0 (1.9)	64.2 (1.8)	58.1 (1.8)	60.2 (1.7)	5.5	**1.24 (1.02-1.50)**	1.10 (0.88-1.37)
Lung	C33-C34	143,935	19.5 (0.4)	19.5 (0.4)	18.3 (0.4)	18.3 (0.4)	17.7 (0.4)	1.8	**1.08 (1.05-1.12)**	**1.10 (1.06-1.14)**
Melanoma	C43	60,379	93.2 (0.4)	93.5 (0.4)	93.2 (0.4)	91.2 (0.5)	91.9 (0.5)	1.3	**1.34 (1.10-1.63)**	1.00 (0.82-1.23)
Soft tissue	C49	8,024	67.4 (2.0)	68.2 (2.0)	68.1 (1.9)	67.8 (2.0)	68.0 (2.0)	-0.6	1.05 (0.85-1.29)	1.16 (0.83-1.63)
Breast	C50	205,897	85.1 (0.4)	84.8 (0.4)	83.9 (0.4)	84.2 (0.4)	83.5 (0.4)	1.6	**1.20 (1.11-1.29)**	**1.58 (1.45-1.71)**
Cervix	C53	14,538	66.0 (1.4)	66.5 (1.4)	66.6 (1.4)	64.4 (1.2)	64.0 (1.4)	2.0	1.13 (0.96-1.32)	1.19 (0.98-1.43)
Corpus uteri	C54	33,449	79.1 (0.9)	80.3 (0.9)	78.8 (0.9)	78.4 (0.8)	78.6 (0.8)	0.5	1.05 (0.91-1.21)	1.08 (0.91-1.30)
Ovary	C56	21,945	44.8 (1.1)	41.3 (1.1)	41.5 (1.1)	40.6 (1.1)	37.9 (1.1)	6.9	**1.36 (1.23-1.50)**	**1.37 (1.21-1.56)**
Prostate	C61	194,052	90.4 (0.6)	89.7 (0.6)	89.0 (0.5)	88.4 (0.8)	87.7 (0.7)	2.7	**1.61 (1.41-1.84)**	1.12 (0.99-1.26)
Testis	C62	12,700	92.2 (2.3)	92.7 (2.1)	93.2 (2.1)	92.7 (2.2)	90.9 (2.6)	1.3	**2.28 (1.23-4.21)**	-[c]
Kidney	C64	47,578	76.5 (0.9)	76.2 (0.8)	75.8 (0.8)	74.3 (0.7)	74.9 (0.7)	1.6	1.11 (0.99-1.25)	1.04 (0.90-1.20)
Bladder	C67	46,880	56.6 (1.0)	56.3 (0.9)	57.1 (0.9)	54.9 (0.9)	55.0 (0.9)	1.6	1.02 (0.94-1.11)	**1.12 (1.00-1.24)**
Brain	C71-C72	18,710	30.1 (1.0)	28.1 (1.0)	27.6 (1.0)	29.4 (1.0)	30.5 (1.0)	-0.4	1.06 (0.97-1.15)	n/a[d]
Thyroid	C73	17,869	91.9 (0.9)	92.0 (1.0)	90.4 (1.0)	89.8 (0.9)	87.8 (1.0)	4.1	**2.06 (1.45-2.93)**	**1.64 (1.12-2.40)**
Hodgkin lymphoma	C81	6,078	86.4 (1.3)	86.9 (1.4)	86.4 (1.3)	85.4 (1.3)	85.3 (1.4)	1.1	0.98 (0.68-1.43)	n/a[d]
Non-Hodgkin lymphoma	C82-C85	43,743	69.7 (0.8)	70.0 (0.8)	67.7 (0.8)	68.7 (0.8)	66.1 (0.8)	3.6	**1.21 (1.09-1.34)**	n/a[d]
Multiple myeloma	C90	18,157	54.5 (1.4)	54.0 (1.3)	50.9 (1.3)	53.3 (1.2)	52.0 (1.3)	2.5	**1.21 (1.07-1.37)**	n/a[d]
Leukemia	C91-C96	34,506	57.0 (1.0)	59.1 (1.0)	58.7 (0.9)	59.1 (0.9)	57.7 (0.9)	-0.7	1.00 (0.91-1.10)	n/a[d]
All cancer sites[b]		1,317,900	61.6 (0.2)	61.2 (0.2)	60.4 (0.2)	59.9 (0.2)	59.0 (0.2)	2.6	**1.16 (1.14-1.18)**	**1.16 (1.14-1.19)**

[a]Difference of GIMD quintiles; [b]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix. [c]Results not shown due to low number of cases of death; [d]No adjustment for stage as no stage information was available (mostly not applicable) for these cancer sites; Abbreviations: GIMD, German Index of Multiple Deprivation, ICD-10, International Classification of Diseases Version 10; n/a, not applicable; Q, quintile.

Table 10 Relative excess risks for 5-year age-standardized survival in 2012-2014 by GIMD quintile and cancer for cancer patients in Germany

	GIMD Quintiles Relative excess risk of 5-year relative survival (95 % Confidence Intervals)[a]			
Cancer site	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**
Oral	1.06 (0.97-1.16)	**1.18 (1.08-1.29)**	**1.24 (1.14-1.35)**	**1.36 (1.25-1.48)**
Esophagus	1.02 (0.93-1.12)	0.97 (0.88-1.07)	1.09 (0.99-1.20)	**1.16 (1.06-1.27)**
Stomach	0.99 (0.93-1.06)	1.01 (0.95-1.08)	1.06 (1.00-1.13)	**1.11 (1.04-1.18)**
Colon and rectum	**1.08 (1.03-1.13)**	**1.13 (1.08-1.19)**	**1.16 (1.10-1.21)**	**1.23 (1.18-1.29)**
Liver	1.05 (0.96-1.15)	**1.13 (1.04-1.23)**	**1.21 (1.12-1.32)**	**1.21 (1.11-1.31)**
Gallbladder	1.09 (0.97-1.22)	**1.17 (1.05-1.31)**	**1.16 (1.05-1.29)**	**1.15 (1.04-1.28)**
Pancreas	1.03 (0.97-1.08)	**1.09 (1.03-1.15)**	**1.06 (1.00-1.12)**	**1.12 (1.06-1.18)**
Larynx	1.19 (0.97-1.46)	1.01 (0.82-1.24)	**1.39 (1.15-1.68)**	**1.24 (1.02-1.50)**
Lung	1.00 (0.97-1.04)	**1.05 (1.01-1.08)**	**1.05 (1.01-1.08)**	**1.08 (1.05-1.12)**
Melanoma	0.95 (0.77-1.18)	1.02 (0.83-1.25)	**1.43 (1.18-1.73)**	**1.34 (1.10-1.63)**
Soft tissue	0.89 (0.72-1.11)	0.93 (0.75-1.16)	0.94 (0.76-1.16)	1.05 (0.85-1.29)
Breast	1.00 (0.92-1.08)	**1.12 (1.03-1.21)**	1.08 (1.00-1.16)	**1.20 (1.11-1.29)**
Cervix	0.99 (0.83-1.17)	1.01 (0.85-1.19)	1.11 (0.95-1.30)	1.13 (0.96-1.32)
Corpus uteri	0.91 (0.77-1.06)	1.04 (0.90-1.21)	1.07 (0.93-1.24)	1.05 (0.91-1.21)
Ovary	**1.19 (1.08-1.32)**	**1.18 (1.06-1.30)**	**1.22 (1.10-1.35)**	**1.36 (1.23-1.50)**
Prostate	**1.18 (1.02-1.36)**	**1.46 (1.27-1.67)**	**1.46 (1.28-1.67)**	**1.61 (1.41-1.84)**
Testis	0.99 (0.48-2.03)	1.05 (0.51-2.18)	1.66 (0.87-3.15)	**2.28 (1.23-4.21)**
Kidney	0.98 (0.86-1.11)	1.02 (0.90-1.15)	1.11 (0.99-1.25)	1.11 (0.99-1.25)
Bladder	1.00 (0.92-1.09)	0.96 (0.88-1.04)	1.04 (0.96-1.13)	1.02 (0.94-1.11)
Brain	1.08 (0.99-1.18)	1.08 (0.99-1.18)	1.05 (0.96-1.15)	1.06 (0.97-1.15)
Thyroid	1.33 (0.90-1.95)	**1.52 (1.03-2.22)**	**1.79 (1.25-2.56)**	**2.06 (1.45-2.93)**
Hodgkin lymphoma	0.86 (0.59-1.26)	0.96 (0.66-1.40)	1.14 (0.80-1.64)	0.98 (0.68-1.43)
Non-Hodgkin lymphoma	1.01 (0.91-1.12)	**1.14 (1.03-1.26)**	1.07 (0.97-1.19)	**1.21 (1.09-1.34)**
Multiple myeloma	1.08 (0.95-1.22)	**1.20 (1.06-1.36)**	1.13 (1.00-1.28)	**1.21 (1.07-1.37)**
Leukemia	0.96 (0.87-1.06)	0.97 (0.88-1.08)	0.94 (0.85-1.04)	1.00 (0.91-1.10)
All cancer sites	**1.03 (1.01-1.05)**	**1.08 (1.07-1.10)**	**1.10 (1.09-1.12)**	**1.16 (1.14-1.18)**

[a]Reference: Q1 (least deprived); Abbreviations: GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases Version 10; Q, quintile.

Table 11 Subgroup analysis of 5-year relative survival in 2012-2014 across GIMD quintiles by age, sex, and stage for the four most common cancer sites

Cancer site, subgroup	Number of cases	5-year relative survival rate (standard error)[a]						Relative excess risk (95 % confidence interval)	
		Q1	Q2	Q3	Q4	Q5	Q1-Q5[b]	Q5[c]	Q5[d]
Breast cancer									
Age ≤ 65 years	112,839	66.0 (0.4)	64.7 (0.5)	65.0 (0.5)	65.6 (0.4)	64.7 (0.5)	1.3	**1.26 (1.14-1.41)**	**1.86 (1.65-2.10)**
Age > 65 years	90,721	46.4 (0.4)	46.3 (0.3)	45.5 (0.3)	45.7 (0.3)	45.4 (0.3)	1.0	**1.14 (1.03-1.27)**	**1.34 (1.19-1.51)**
Local stage	105,045	96.3 (0.5)	96.1 (0.5)	95.6 (0.5)	96.5 (0.4)	95.1 (0.5)	1.2	**1.49 (1.12-1.97)**	n/a
Regional stage	55,271	85.0 (0.7)	84.0 (0.7)	83.8 (0.7)	82.8 (0.7)	83.1 (0.7)	1.9	**1.24 (1.07-1.43)**	n/a
Advanced stage	26,508	65.9 (1.0)	60.7 (1.1)	60.3 (1.1)	56.3 (1.1)	55.9 (1.1)	10.0	**1.60 (1.44-1.78)**	n/a
Prostate cancer									
Age ≤ 65 years	53,614	68.2 (0.6)	67.3 (0.6)	67.3 (0.6)	66.5 (0.8)	65.8 (0.8)	2.4	**2.11 (1.60-2.79)**	1.11 (0.88-1.40)
Age > 65 years	129,589	51.1 (0.3)	50.6 (0.3)	49.7 (0.3)	50.0 (0.3)	49.5 (0.3)	1.6	**1.47 (1.27-1.70)**	1.11 (0.96-1.29)
Local stage	93,560	100.3 (0.7)	99.9 (0.5)	99.5 (0.5)	98.9 (0.5)	97.8 (0.5)	2.5	1.82 (0.81-4.09)	n/a
Regional stage	6,282	84.1 (2.8)	78.3 (3.3)	80.0 (3.2)	76.3 (2.9)	82.8 (2.9)	1.3	1.30 (0.69-2.47)	n/a
Advanced stage	11,136	26.0 (1.7)	30.8 (2.5)	23.3 (1.5)	25.4 (1.6)	28.6 (2.9)	-2.6	1.08 (0.95-1.22)	n/a
Colorectal cancer									
Men	105,330	64.6 (0.6)	63.2 (0.6)	62.0 (0.6)	61.8 (0.6)	60.1 (0.6)	4.5	**1.28 (1.21-1.37)**	**1.24 (1.15-1.32)**
Women	85,104	67.0 (0.6)	65.5 (0.6)	64.9 (0.6)	64.7 (0.6)	64.5 (0.6)	2.5	**1.17 (1.09-1.25)**	**1.10 (1.02-1.19)**
Age ≤ 65 years	56,468	49.9 (0.8)	47.8 (0.8)	48.8 (0.8)	48.9 (0.8)	47.2 (0.8)	2.7	**1.24 (1.14-1.35)**	**1.23 (1.13-1.35)**
Age > 65 years	130,617	35.1 (0.3)	34.4 (0.3)	33.6 (0.3)	33.3 (0.3)	32.9 (0.3)	2.2	**1.23 (1.17-1.30)**	**1.16 (1.09-1.23)**
Local stage	60,578	87.9 (0.6)	86.9 (0.6)	85.3 (0.6)	86.1 (0.6)	85.1 (0.6)	2.8	**1.45 (1.23-1.70)**	n/a
Regional stage	36,577	70.2 (1.0)	69.5 (0.9)	69.1 (0.9)	68.6 (0.9)	67.0 (0.9)	3.2	**1.19 (1.06-1.33)**	n/a
Advanced stage	60,716	42.0 (0.8)	41.9 (0.7)	43.1 (0.7)	37.7 (0.7)	38.6 (0.7)	3.4	**1.12 (1.05-1.19)**	n/a
Lung cancer									
Men	98,875	18.5 (0.6)	18.0 (0.5)	16.5 (0.5)	16.6 (0.4)	15.8 (0.4)	2.7	**1.09 (1.05-1.14)**	**1.11 (1.06-1.16)**
Women	45,060	21.5 (0.7)	22.3 (0.7)	21.3 (0.6)	21.4 (0.6)	21.3 (0.7)	0.2	1.04 (0.98-1.09)	1.04 (0.98-1.11)
Age ≤ 65 years	53,999	15.2 (0.7)	16.0 (0.7)	15.4 (0.7)	15.1 (0.6)	15.6 (0.7)	-0.4	**1.07 (1.02-1.12)**	**1.09 (1.03-1.15)**
Age > 65 years	84,383	9.6 (0.3)	9.4 (0.3)	8.3 (0.2)	8.9 (0.2)	8.3 (0.2)	1.3	**1.09 (1.05-1.14)**	**1.11 (1.06-1.16)**
Local stage	18,776	57.2 (1.5)	57.0 (1.5)	54.7 (1.4)	54.7 (1.3)	55.2 (1.2)	2.0	1.12 (0.99-1.27)	n/a
Regional stage	24,481	23.5 (1.2)	23.6 (1.1)	21.8 (1.0)	20.9 (0.9)	20.2 (0.9)	3.3	**1.16 (1.07-1.25)**	n/a
Advanced stage	60,748	9.6 (0.5)	10.8 (0.5)	10.5 (0.5)	9.0 (0.4)	8.4 (0.4)	1.2	**1.07 (1.02-1.12)**	n/a

[a]age-standardized; [b]Difference of GIMD quintiles; [c]Reference: Q1 (least deprived), adjusted for age at diagnosis, including patients with missing stage information; [d]Reference: Q1 (least deprived), adjusted for age at diagnosis and stage at diagnosis, excluding patients with missing stage information. Abbreviations: GIMD, German Index of Multiple Deprivation; n/a, not applicable; Q, quintile.

Table 12 Subgroup analysis of 5-year relative survival in 2012-2014 across GIMD quintiles by age and sex for the four most common cancer sites, including only patients with available stage information

Cancer site, subgroup	Number of cases	GIMD Quintiles 5-year relative survival (standard error)						Relative excess risk (95 % confidence interval)
		Q1	Q2	Q3	Q4	Q5	Q1-Q5[a]	Q5[b]
Breast cancer								
Age ≤ 65 years	105940	67.2 (0.4)	66.0 (0.5)	65.9 (0.5)	66.4 (0.4)	65.2 (0.5)	2.0	**1.42 (1.26-1.61)**
Age > 65 years	80884	48.3 (0.4)	48.3 (0.4)	47.6 (0.4)	47.9 (0.3)	47.4 (0.4)	0.9	1.13 (1.00-1.29)
Prostate cancer								
Age ≤ 65 years	36366	67.9 (0.9)	67.2 (0.8)	67.7 (0.7)	66.0 (1.2)	65.7 (0.9)	2.2	**1.78 (1.29-2.44)**
Age > 65 years	74612	51.8 (0.6)	52.0 (0.5)	51.2 (0.5)	51.0 (0.4)	51.3 (0.4)	0.5	1.22 (0.95-1.57)
Colorectal cancer								
Men	87763	65.2 (0.7)	63.8 (0.6)	62.7 (0.6)	63.1 (0.6)	61.6 (0.6)	3.6	**1.23 (1.14-1.31)**
Women	70108	67.2 (0.7)	66.9 (0.7)	66.3 (0.7)	66.1 (0.6)	66.0 (0.7)	1.2	**1.09 (1.01-1.18)**
Age ≤ 65 years	48201	49.1 (1.0)	47.7 (0.9)	48.6 (0.9)	49.2 (0.9)	46.9 (0.9)	2.2	**1.18 (1.08-1.29)**
Age > 65 years	109670	36.3 (0.4)	35.8 (0.4)	35.0 (0.3)	34.9 (0.3)	34.7 (0.3)	1.6	**1.16 (1.09-1.24)**
Lung cancer								
Men	71948	19.9 (0.6)	20.3 (0.6)	18.6 (0.6)	18.2 (0.5)	17.4 (0.5)	2.5	**1.09 (1.04-1.14)**
Women	32057	24.0 (0.9)	26.1 (1.0)	24.5 (0.8)	24.1 (0.8)	23.9 (0.8)	0.1	1.02 (0.96-1.09)
Age ≤ 65 years	43309	15.8 (0.8)	17.2 (0.9)	16.4 (0.8)	16.1 (0.8)	16.6 (0.8)	-0.8	**1.06 (1.00-1.12)**
Age > 65 years	60696	11.1 (0.4)	11.5 (0.4)	10.2 (0.3)	10.4 (0.3)	9.9 (0.3)	1.2	**1.09 (1.04-1.15)**

[a]Difference of GIMD quintiles; [b]Reference: Q1 (least deprived), adjusted for age at diagnosis; Abbreviations: GIMD, German Index of Multiple Deprivation; n/a, not applicable; Q, quintile.

Table 13 Comparison of 3-month, 1-year and 5-year conditional on 1-year age-standardized relative survival in 2012-2014 for the most deprived quintile (Q5) by cancer site

	Relative excess risk (95 % confidence interval) for Q5 versus Q1					
	Without stage adjustment			With stage adjustment		
Cancer site	**3-month RS**	**1-year RS**	**5-year conditional on 1-year RS**	**3-month RS**	**1-year RS**	**5-year conditional on 1-year RS**
Oral	**1.46 (1.11-1.93)**	**1.41 (1.24-1.60)**	**1.33 (1.19-1.48)**	**1.74 (1.21-2.49)**	**1.60 (1.37-1.86)**	**1.34 (1.19-1.51)**
Esophagus	1.16 (0.92-1.45)	**1.20 (1.07-1.35)**	1.10 (0.95-1.26)	**1.55 (1.09-2.18)**	**1.27 (1.09-1.48)**	0.95 (0.81-1.12)
Stomach	**1.27 (1.09-1.47)**	**1.08 (1.00-1.18)**	**1.14 (1.03-1.26)**	**1.40 (1.13-1.74)**	1.11 (1.00-1.23)	1.08 (0.96-1.21)
Colon and rectum	**1.35 (1.21-1.51)**	**1.32 (1.24-1.41)**	**1.16 (1.09-1.23)**	**1.30 (1.14-1.49)**	**1.23 (1.14-1.33)**	**1.14 (1.06-1.22)**
Liver	**1.28 (1.08-1.52)**	**1.19 (1.08-1.31)**	**1.24 (1.07-1.43)**	1.21 (0.89-1.64)	1.14 (0.96-1.36)	1.07 (0.85-1.33)
Gallbladder	1.21 (0.96-1.51)	**1.19 (1.04-1.36)**	1.11 (0.94-1.32)	1.29 (0.93-1.80)	**1.21 (1.01-1.45)**	1.07 (0.87-1.32)
Pancreas	**1.32 (1.18-1.48)**	**1.16 (1.09-1.24)**	1.03 (0.93-1.14)	**1.39 (1.20-1.61)**	**1.13 (1.04-1.22)**	0.99 (0.89-1.11)
Larynx	**3.00 (1.26-7.12)**	1.27 (0.91-1.76)	1.23 (0.97-1.55)	5.22 (0.89-30.65)	1.45 (0.94-2.24)	0.98 (0.76-1.27)
Lung	**1.25 (1.16-1.34)**	**1.11 (1.07-1.16)**	1.03 (0.98-1.09)	**1.31 (1.19-1.43)**	**1.12 (1.07-1.17)**	1.05 (0.99-1.11)
Melanoma	-[d]	**2.11 (1.32-3.36)**	1.18 (0.95-1.47)	**2.25 (1.03-4.89)**	1.01 (0.70-1.45)	0.98 (0.77-1.24)
Soft tissue	**2.23 (1.18-4.23)**	1.12 (0.83-1.52)	0.97 (0.72-1.30)	1.58 (0.60-4.19)	1.44 (0.85-2.45)	0.92 (0.58-1.45)
Breast	**1.53 (1.05-2.23)**	**1.43 (1.22-1.68)**	**1.14 (1.05-1.24)**	1.31 (0.93-1.86)	**1.27 (1.07-1.50)**	**1.57 (1.43-1.73)**
Cervix	1.77 (0.95-3.31)	1.17 (0.92-1.48)	1.11 (0.90-1.37)	2.15 (0.85-5.45)	1.21 (0.90-1.64)	1.15 (0.90-1.46)
Corpus uteri	1.28 (0.79-2.06)	1.09 (0.87-1.38)	1.01 (0.84-1.22)	1.10 (0.63-1.92)	1.02 (0.76-1.36)	1.06 (0.85-1.33)
Ovary	**1.44 (1.10-1.89)**	**1.45 (1.24-1.70)**	**1.28 (1.12-1.45)**	1.20 (0.78-1.83)	**1.36 (1.09-1.71)**	**1.35 (1.16-1.57)**
Prostate	**2.17 (1.14-4.15)**	**1.97 (1.52-2.55)**	**1.48 (1.27-1.72)**	1.28 (0.66-2.49)	**1.43 (1.10-1.85)**	1.02 (0.89-1.18)
Testis	1.98 (0.49-8.00)	**2.78 (1.20-6.47)**	2.21 (0.84-5.84)	-[e]	-[d]	-[d]
Kidney	**1.42 (1.05-1.91)**	1.03 (0.88-1.20)	**1.23 (1.03-1.48)**	1.14 (0.75-1.71)	0.86 (0.70-1.04)	**1.28 (1.03-1.58)**
Bladder	1.16 (0.92-1.47)	1.09 (0.98-1.21)	0.94 (0.84-1.06)	**2.12 (1.37-3.27)**	**1.21 (1.05-1.41)**	0.98 (0.85-1.14)
Brain	1.23 (0.97-1.55)	**1.14 (1.02-1.28)**	0.95 (0.83-1.09)	n/a[f]	n/a[f]	n/a[f]
Thyroid	1.68 (0.85-3.32)	**2.15 (1.41-3.26)**	**1.90 (1.02-3.52)**	1.06 (0.49-2.32)	1.58 (0.97-2.57)	1.77 (0.98-3.21)
Hodgkin lymphoma	1.28 (0.47-3.51)	0.83 (0.51-1.36)	1.32 (0.75-2.31)	n/a[f]	n/a[f]	n/a[f]
Non-Hodgkin lymphoma	**1.31 (1.04-1.66)**	**1.17 (1.03-1.33)**	**1.28 (1.09-1.50)**	n/a[f]	n/a[f]	n/a[f]
Multiple myeloma	**1.76 (1.17-2.65)**	**1.58 (1.28-1.94)**	1.04 (0.89-1.21)	n/a[f]	n/a[f]	n/a[f]
Leukemia	1.10 (0.87-1.40)	1.08 (0.96-1.23)	0.89 (0.77-1.04)	n/a[f]	n/a[f]	n/a[f]
All cancer sites[c]	**1.31 (1.25-1.36)**	**1.19 (1.16-1.21)**	**1.12 (1.09-1.15)**	**1.36 (1.28-1.44)**	**1.18 (1.15-1.20)**	**1.14 (1.11-1.18)**

[a]Reference: Q1 (least deprived), adjusted for age at diagnosis, total population; [b]Reference: Q1 (least deprived), adjusted for age at diagnosis and stage at diagnosis, excluding patients with missing stage information. [c]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix; [d]Results not shown due to low number of cases of death; [e]Model did not converge; [f]No adjustment for stage as no stage information was available for these cancer sites; Abbreviations: RS, relative survival; Q, quintile.

Table 14 Three-month age-standardized relative survival in 2012-2014 by GIMD quintile and cancer site for cancer patients in Germany

		GIMD Quintiles					
		3-months relative survival (standard error)					
Cancer site	Number of cases	Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)	Q1-Q5[a]
Oral	15,825	95.2 (0.5)	95.1 (0.4)	94.7 (0.4)	95.0 (0.4)	93.6 (0.5)	1.6
Esophagus	7,487	87.6 (0.8)	88.5 (0.8)	87.7 (0.8)	86.7 (0.8)	85.9 (0.8)	1.7
Stomach	18,096	89.0 (0.5)	88.7 (0.5)	88.2 (0.5)	88.1 (0.5)	86.8 (0.5)	2.2
Colon and rectum	69,332	95.0 (0.2)	94.7 (0.2)	94.5 (0.2)	94.3 (0.2)	94.0 (0.2)	1.0
Liver	9,154	81.4 (1.0)	80.0 (1.0)	79.4 (1.0)	77.1 (1.0)	77.6 (0.9)	3.8
Gallbladder	5,701	84.0 (1.2)	82.4 (1.2)	82.5 (1.1)	82.4 (1.0)	81.9 (1.1)	2.1
Pancreas	17,983	80.8 (0.7)	78.9 (0.7)	78.3 (0.7)	78.2 (0.6)	77.3 (0.6)	3.5
Larynx	4,020	97.5 (0.7)	97.0 (0.7)	96.5 (0.8)	96.6 (0.7)	95.7 (0.7)	1.8
Lung	57,411	83.9 (0.4)	83.1 (0.4)	82.7 (0.3)	82.2 (0.3)	81.6 (0.3)	2.3
Melanoma	23,747	100 (0.1)	100.0 (0.1)	99.9 (0.1)	99.8 (0.1)	99.6 (0.1)	0.4
Soft tissue	3,157	96.6 (0.8)	96.1 (0.8)	96.7 (0.7)	96.2 (0.7)	94.0 (1.0)	2.6
Breast	78,031	99.3 (0.1)	99.2 (0.1)	99.2 (0.1)	99.1 (0.1)	99.1 (0.1)	0.2
Cervix	5,197	97.3 (0.6)	97.0 (0.6)	95.7 (0.6)	95.3 (0.6)	96.2 (0.6)	1.1
Corpus uteri	12,161	97.9 (0.3)	98.2 (0.3)	97.8 (0.3)	98.0 (0.3)	97.8 (0.3)	0.1
Ovary	7,975	91.5 (0.7)	90.1 (0.7)	90.3 (0.7)	89.7 (0.7)	89.6 (0.7)	1.9
Prostate	69,340	99.7 (0.1)	99.7 (0.1)	99.4 (0.1)	99.5 (0.1)	99.5 (0.1)	0.2
Testis	4,650	98.4 (1.1)	98.8 (1.0)	98.3 (1.0)	98.0 (1.0)	98.5 (0.9)	-0.1
Kidney	18,153	96.5 (0.4)	96.8 (0.3)	96.6 (0.3)	96.1 (0.3)	95.6 (0.3)	0.9
Bladder	18,604	95.4 (0.4)	95.4 (0.4)	95.2 (0.4)	94.5 (0.4)	94.6 (0.4)	0.8
Brain	7,325	90.9 (0.6)	90.7 (0.6)	90.1 (0.6)	89.8 (0.6)	89.8 (0.6)	1.1
Thyroid	6,122	98.2 (0.4)	97.6 (0.5)	97.6 (0.5)	97.3 (0.5)	97.3 (0.5)	0.9
Hodgkin lymphoma	2,362	98.7 (0.5)	98.2 (0.5)	97.7 (0.6)	97.8 (0.5)	98.2 (0.5)	0.5
Non-Hodgkin lymphoma	16,834	94.4 (0.4)	94.1 (0.4)	93.5 (0.4)	93.9 (0.4)	93.6 (0.4)	0.8
Multiple myeloma	7,095	95.8 (0.6)	94.7 (0.5)	94.2 (0.5)	94.6 (0.5)	94.3 (0.5)	1.5
Leukemia	13,444	92.7 (0.5)	92.5 (0.5)	91.7 (0.5)	92.2 (0.5)	92.5 (0.5)	0.2
All cancer sites[b]	499,206	93.9 (0.1)	93.6 (0.1)	93.2 (0.1)	93.0 (0.1)	92.8 (0.1)	1.1

[a]Difference of GIMD quintiles; [b]Analyses for all cancer sites combined are weighted (survival rates) for case mix. Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile.

Table 15 One-year age-standardized relative survival in 2012-2014 by GIMD quintile and cancer site for cancer patients in Germany

		GIMD Quintiles					
		1-year relative survival (standard error)					
Cancer site	Number of cases	Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)	Q1-Q5[a]
Oral	20,372	78.4 (0.9)	78.3 (0.8)	76.6 (0.8)	76.7 (0.8)	75.1 (0.8)	3.3
Esophagus	9,384	55.4 (1.3)	53.1 (1.2)	53.7 (1.2)	51.4 (1.2)	50.6 (1.2)	4.8
Stomach	23,455	61.9 (0.8)	62.1 (0.8)	62.1 (0.7)	60.4 (0.7)	59.5 (0.7)	2.4
Colon and rectum	90,640	85.4 (0.3)	84.5 (0.3)	84.0 (0.3)	83.6 (0.3)	82.8 (0.3)	2.6
Liver	11,481	48.9 (1.3)	48.0 (1.3)	45.8 (1.2)	43.3 (1.1)	43.2 (1.1)	5.7
Gallbladder	7,301	55.5 (1.7)	53.4 (1.6)	53.2 (1.3)	51.1 (1.3)	52.9 (1.4)	2.6
Pancreas	22,407	42.3 (0.9)	41.1 (0.8)	38.8 (0.8)	40.1 (0.8)	37.3 (0.8)	5.0
Larynx	5,289	86.8 (1.4)	83.4 (1.5)	85.3 (1.3)	84.9 (1.3)	84.9 (1.2)	1.9
Lung	72,233	48.8 (0.5)	48.6 (0.5)	47.7 (0.4)	47.0 (0.4)	45.8 (0.4)	3.0
Melanoma	30,789	99.1 (0.2)	99.0 (0.2)	98.5 (0.2)	98.2 (0.2)	98.3 (0.2)	0.8
Soft tissue	4,057	86.6 (1.4)	87.5 (1.3)	87.9 (1.2)	87.6 (1.2)	85.2 (1.4)	1.4
Breast	99,009	96.7 (0.2)	96.6 (0.2)	96.2 (0.2)	95.9 (0.2)	95.8 (0.2)	0.9
Cervix	6,835	85.3 (1.1)	85.9 (1.1)	84.7 (1.1)	83.7 (1.0)	83.6 (1.1)	1.7
Corpus uteri	15,932	91.9 (0.6)	92.7 (0.5)	92.4 (0.5)	92.3 (0.5)	92.1 (0.5)	-0.2
Ovary	10,278	76.9 (1.0)	73.9 (1.0)	73.4 (0.9)	72.6 (1.0)	71.8 (1.0)	5.1
Prostate	91,033	97.7 (0.3)	97.6 (0.2)	97.2 (0.2)	96.9 (0.5)	96.9 (0.2)	0.8
Testis	6,021	95.2 (1.7)	95.7 (1.6)	95.4 (1.4)	94.1 (1.5)	93.1 (1.7)	2.1
Kidney	23,320	87.9 (0.6)	88.5 (0.5)	88.5 (0.5)	86.9 (0.5)	87.5 (0.5)	0.4
Bladder	23,461	79.9 (0.7)	79.2 (0.7)	79.3 (0.7)	77.9 (0.7)	77.6 (0.7)	2.3
Brain	9,320	62.3 (1.0)	60.0 (1.0)	59.8 (1.0)	60.6 (1.0)	60.6 (0.9)	1.7
Thyroid	8,433	95.2 (0.7)	94.6 (0.7)	94.0 (0.7)	92.3 (0.7)	92.2 (0.7)	3.0
Hodgkin lymphoma	3,004	92.9 (1.0)	94.5 (0.9)	92.5 (0.9)	92.5 (0.9)	93.5 (0.9)	-0.6
Non-Hodgkin lymphoma	21,764	82.9 (0.6)	82.9 (0.6)	81.9 (0.6)	82.3 (0.6)	81.4 (0.6)	1.5
Multiple myeloma	9,178	85.6 (1.0)	84.3 (0.9)	82.6 (0.9)	84.0 (0.8)	81.1 (0.9)	4.5
Leukemia	17,299	76.4 (0.8)	76.3 (0.8)	76.2 (0.7)	76.2 (0.7)	76.1 (0.7)	0.3
All cancer sites[b]	642,295	80.0 (0.1)	79.6 (0.1)	79.0 (0.1)	78.5 (0.1)	77.9 (0.1)	2.1

[a]Difference of GIMD quintiles; [b]Analyses for all cancer sites combined are weighted (survival rates) for case mix. Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile.

Table 16 Five-year conditional on one-year age-standardized relative survival in 2012-2014 by GIMD quintile and cancer site for cancer patients in Germany

		GIMD Quintiles					
		5-year conditional on1-year relative survival (standard error)					
Cancer site	Number of cases	Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)	Q1-Q5[a]
Oral	40,971	65.4 (1.2)	66.9 (1.2)	64.8 (1.2)	62.5 (1.2)	60.5 (1.2)	4.9
Esophagus	18,629	44.4 (1.9)	43.9 (2.0)	47.0 (1.9)	43.4 (1.9)	40.6 (1.9)	3.8
Stomach	48,850	54.6 (1.1)	54.5 (1.1)	54.0 (1.0)	54.3 (1.0)	51.1 (1.0)	3.5
Colon and rectum	190,434	76.3 (0.4)	75.3 (0.4)	74.9 (0.4)	74.7 (0.4)	74.2 (0.4)	2.1
Liver	22,069	39.1 (1.9)	36.7 (1.8)	36.4 (1.8)	33.0 (1.7)	33.9 (1.7)	5.2
Gallbladder	14,645	43.7 (2.3)	43.7 (2.4)	40.0 (2.2)	45.1 (2.1)	40.5 (2.1)	3.2
Pancreas	42,841	29.1 (1.3)	30.0 (1.4)	27.0 (1.3)	30.5 (1.3)	28.0 (1.3)	1.1
Larynx	11,021	74.8 (2.0)	74.7 (2.0)	74.3 (1.9)	67.8 (1.9)	69.8 (1.8)	5.0
Lung	143,935	39.2 (0.7)	39.4 (0.7)	37.2 (0.7)	38.2 (0.7)	37.7 (0.7)	1.5
Melanoma	60,379	93.7 (0.4)	94.1 (0.4)	94.2 (0.4)	92.5 (0.4)	93.1 (0.4)	0.6
Soft tissue	8,024	77.3 (1.9)	77.4 (1.9)	77.0 (1.9)	76.9 (1.9)	79.1 (1.9)	-1.8
Breast	205,897	87.6 (0.4)	87.4 (0.3)	86.7 (0.3)	87.4 (0.3)	86.6 (0.3)	1.0
Cervix	14,538	76.0 (1.5)	76.4 (1.5)	77.4 (1.4)	75.0 (1.3)	75.1 (1.5)	0.9
Corpus uteri	33,449	85.5 (0.9)	86.1 (0.9)	84.8 (0.8)	84.5 (0.8)	84.9 (0.8)	0.6
Ovary	21,945	56.6 (1.4)	53.6 (1.4)	54.8 (1.4)	54.1 (1.4)	50.6 (1.4)	6.0
Prostate	194,052	91.7 (0.5)	91.1 (0.5)	90.7 (0.5)	90.4 (0.7)	89.7 (0.7)	2.0
Testis	12,700	96.0 (2.4)	96.2 (1.9)	97.5 (1.9)	98.6 (1.8)	98.1 (2.4)	-2.1
Kidney	47,578	86.3 (0.8)	85.3 (0.8)	84.8 (0.7)	84.6 (0.7)	84.9 (0.7)	1.4
Bladder	46,880	69.9 (1.0)	70.2 (1.0)	71.0 (0.9)	69.6 (0.9)	70.0 (0.9)	-0.1
Brain	18,710	41.2 (1.5)	41.0 (1.6)	39.3 (1.5)	41.8 (1.5)	43.7 (1.7)	-2.5
Thyroid	17,869	95.7 (0.8)	96.9 (0.9)	95.4 (0.9)	96.6 (0.8)	94.5 (1.0)	1.2
Hodgkin lymphoma	6,078	91.7 (1.4)	91.0 (1.4)	92.1 (1.3)	90.8 (1.4)	90.0 (1.5)	1.7
Non-Hodgkin lymphoma	43,743	82.8 (0.9)	83.1 (0.8)	81.3 (0.8)	82.0 (0.8)	79.7 (0.8)	3.1
Multiple myeloma	18,157	62.3 (1.5)	62.6 (1.4)	60.1 (1.4)	61.5 (1.3)	62.6 (1.4)	-0.3
Leukemia	34,506	73.1 (1.2)	76.0 (1.1)	75.3 (1.0)	76.1 (1.0)	74.2 (1.0)	-1.1
All cancer sites[b]	1,317,900	72.0 (0.2)	71.9 (0.2)	71.1 (0.2)	71.1 (0.2)	70.4 (0.2)	1.6

[a]Difference of GIMD quintiles; [b]Analyses for all cancer sites combined are weighted (survival rates) for case mix. Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile.

Table 17 Comparison of 5-year age-standardized relative survival by GIMD quintile and cancer site for German cancer patients, period 2003-2005 and 2012-2014

	Period 2003-2005				Period 2012-2014			
	5-year relative survival rate (standard error)			Relative excess risk (95 % confidence interval)[a]	5-year relative survival rate (standard error)			Relative excess risk (95 % confidence interval)[a]
Cancer site	**Q1**	**Q5**	**Q1-Q5[b]**	**Q5 (most deprived)**	**Q1**	**Q5**	**Q1-Q5[b]**	**Q5 (most deprived)**
Oral	46.6 (1.7)	43.7 (1.3)	2.9	**1.19 (1.09-1.29)**	52.0 (1.1)	46.0 (1.0)	6.0	**1.36 (1.25-1.48)**
Esophagus	20.8 (1.6)	16.3 (1.1)	4.5	**1.19 (1.08-1.31)**	25.3 (1.2)	21.0 (1.0)	4.3	**1.16 (1.06-1.27)**
Stomach	31.3 (1.0)	27.4 (0.7)	3.9	**1.19 (1.12-1.26)**	34.2 (0.8)	30.8 (0.7)	3.4	**1.11 (1.04-1.18)**
Colon and rectum	61.1 (0.6)	57.6 (0.4)	3.5	**1.28 (1.22-1.34)**	65.7 (0.4)	62.0 (0.4)	3.7	**1.23 (1.18-1.29)**
Liver	15.7 (1.4)	10.3 (0.9)	5.4	**1.33 (1.20-1.46)**	19.7 (1.1)	15.5 (0.9)	4.2	**1.21 (1.11-1.31)**
Gallbladder	20.2 (1.8)	16.5 (1.2)	3.7	**1.26 (1.13-1.40)**	25.4 (1.6)	22.0 (1.4)	3.4	**1.15 (1.04-1.28)**
Pancreas	10.0 (0.8)	7.7 (0.6)	2.3	**1.19 (1.11-1.26)**	13.3 (0.7)	11.3 (0.6)	2.0	**1.12 (1.06-1.18)**
Larynx	67.0 (2.9)	58.6 (2.2)	8.4	**1.51 (1.21-1.88)**	65.7 (2.0)	60.2 (1.7)	5.5	**1.24 (1.02-1.50)**
Lung	15.9 (0.5)	13.8 (0.4)	2.1	**1.12 (1.08-1.16)**	19.5 (0.4)	17.7 (0.4)	1.8	**1.08 (1.05-1.12)**
Melanoma	88.3 (0.9)	85.3 (0.8)	3.0	**1.79 (1.45-2.22)**	93.2 (0.4)	91.9 (0.5)	1.3	**1.34 (1.10-1.63)**
Soft tissue	61.1 (2.5)	56.8 (2.2)	4.3	1.22 (0.97-1.54)	67.4 (2.0)	68.0 (2.0)	-0.6	1.05 (0.85-1.29)
Breast	80.9 (0.6)	79.8 (0.4)	1.1	**1.19 (1.10-1.30)**	85.1 (0.4)	83.5 (0.4)	1.6	**1.20 (1.11-1.29)**
Cervix	63.3 (1.8)	61.5 (1.3)	1.8	1.12 (0.94-1.32)	66.0 (1.4)	64.0 (1.4)	2.0	1.13 (0.96-1.32)
Corpus uteri	78.4 (1.2)	79.0 (0.9)	-0.6	0.98 (0.84-1.16)	79.1 (0.9)	78.6 (0.8)	0.5	1.05 (0.91-1.21)
Ovary	37.1 (1.3)	37.3 (1.0)	-0.2	**1.14 (1.03-1.26)**	44.8 (1.1)	37.9 (1.1)	6.9	**1.36 (1.23-1.50)**
Prostate	85.5 (0.9)	82.7 (0.7)	2.8	**2.07 (1.76-2.43)**	90.4 (0.6)	87.7 (0.7)	2.7	**1.61 (1.41-1.84)**
Testis	85.1 (1.3)	85.2 (2.7)	-0.1	**2.10 (1.27-3.44)**	92.2 (2.3)	90.9 (2.6)	1.3	**2.28 (1.23-4.21)**
Kidney	73.1 (1.3)	68.2 (0.9)	4.9	**1.29 (1.14-1.47)**	76.5 (0.9)	74.9 (0.7)	1.6	1.11 (0.99-1.25)
Bladder	57.3 (1.2)	56.1 (0.9)	1.2	1.07 (0.98-1.17)	56.6 (1.0)	55.0 (0.9)	1.6	1.02 (0.94-1.11)
Brain	27.8 (1.4)	25.9 (1.1)	1.9	**1.11 (1.01-1.22)**	30.1 (1.0)	30.5 (1.0)	-0.4	1.06 (0.97-1.15)
Thyroid	87.9 (1.5)	86.8 (1.2)	1.1	**1.52 (1.05-2.20)**	91.9 (0.9)	87.8 (1.0)	4.1	**2.06 (1.45-2.93)**
Hodgkin lymphoma	83.5 (2.0)	81.5 (1.5)	2.0	**1.82 (1.15-2.88)**	86.4 (1.3)	85.3 (1.4)	1.1	0.98 (0.68-1.43)
Non-Hodgkin lymphoma	59.3 (1.3)	56.8 (1.0)	2.5	**1.23 (1.10-1.37)**	69.7 (0.8)	66.1 (0.8)	3.6	**1.21 (1.09-1.34)**
Multiple myeloma	42.6 (1.9)	38.2 (1.5)	4.4	**1.27 (1.10-1.46)**	54.5 (1.4)	52.0 (1.3)	2.5	**1.21 (1.07-1.37)**
Leukemia	47.4 (1.4)	48.8 (1.1)	-1.4	1.10 (0.99-1.23)	57.0 (1.0)	57.7 (0.9)	-0.7	1.00 (0.91-1.10)
All cancer sites[c]	57.0 (0.2)	54.5 (0.2)	2.5	**1.20 (1.18-1.23)**	61.6 (0.2)	59.0 (0.2)	2.6	**1.16 (1.14-1.18)**

[a]Reference: Q1 (least deprived), adjusted for age at diagnosis; [b]Difference of GIMD quintiles; [c]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix. Abbreviations: GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases Version 10, Q, quintile.

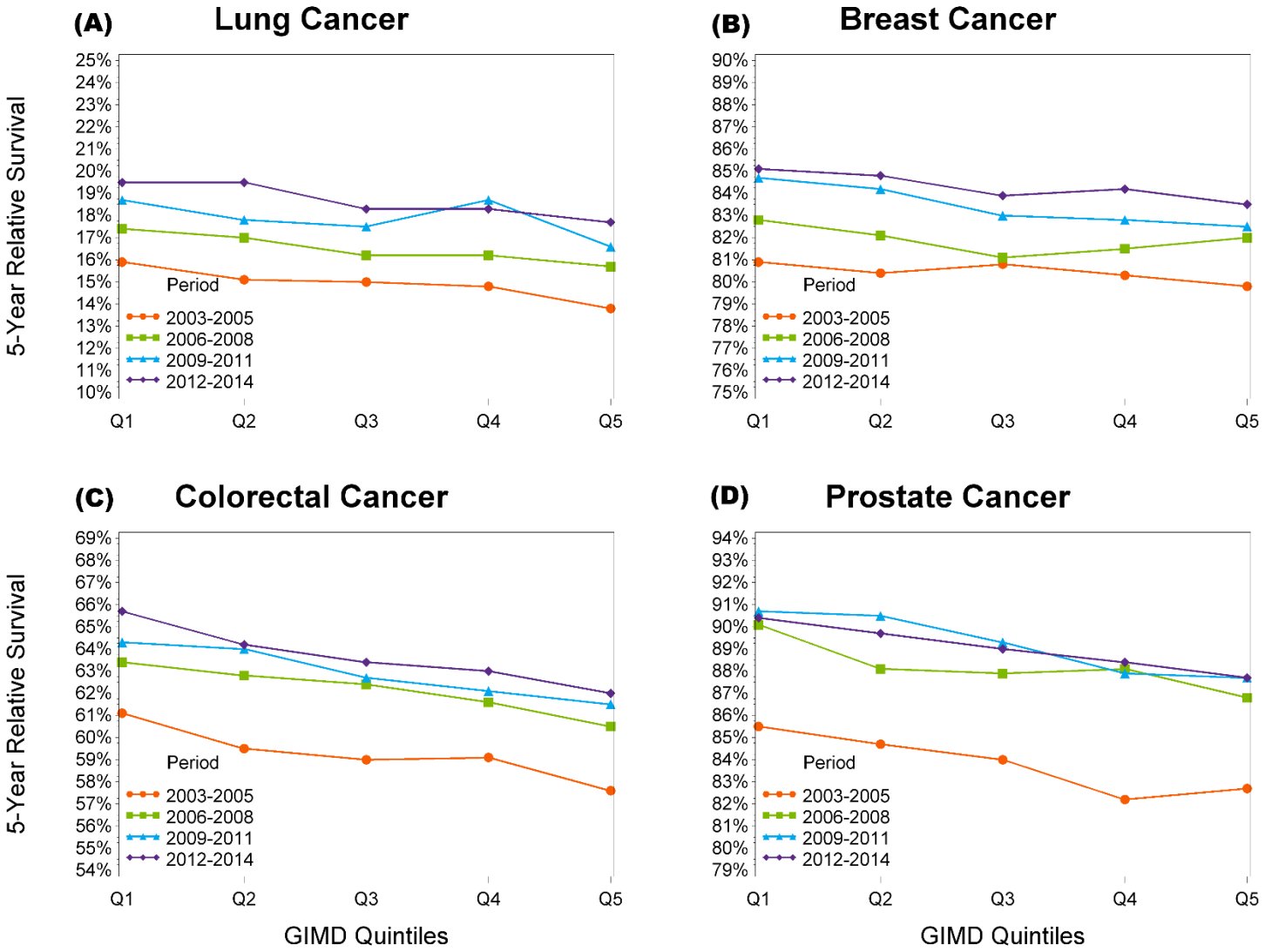

Figure 13 Five-year age-standardized relative survival rates across GIMD quintiles for the four most common cancer sites stratified by calendar period. Ordinate scales are equally reduced to a range of 15%-points

Table 18 Relative excess risks for 5-year age-standardized relative survival in 2012-2014 by GIMD quintile and cancer site for cancer patients in Germany, adjusted for federal state

	GIMD Quintiles Relative excess risk of 5-year relative survival (95 % Confidence Intervals)[a]			
Cancer site	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**
Oral	1.05 (0.95-1.15)	**1.17 (1.07-1.28)**	**1.19 (1.09-1.31)**	**1.32 (1.20-1.45)**
Esophagus	0.99 (0.90-1.09)	0.93 (0.85-1.03)	1.00 (0.91-1.11)	1.05 (0.94-1.16)
Stomach	0.94 (0.87-1.00)	0.95 (0.88-1.01)	0.97 (0.91-1.04)	0.99 (0.93-1.07)
Colon and rectum	1.03 (0.98-1.09)	**1.08 (1.03-1.13)**	**1.07 (1.02-1.13)**	**1.14 (1.08-1.20)**
Liver	0.99 (0.90-1.09)	1.06 (0.97-1.16)	1.09 (0.99-1.20)	1.08 (0.98-1.19)
Gallbladder	1.06 (0.94-1.19)	**1.14 (1.01-1.28)**	1.10 (0.98-1.23)	1.07 (0.95-1.21)
Pancreas	0.99 (0.94-1.05)	1.05 (0.99-1.11)	1.01 (0.95-1.07)	**1.07 (1.01-1.14)**
Larynx	**1.27 (1.03-1.57)**	1.07 (0.87-1.33)	**1.49 (1.21-1.83)**	**1.37 (1.10-1.70)**
Lung	0.99 (0.95-1.02)	1.03 (0.99-1.07)	1.03 (1.00-1.07)	**1.07 (1.03-1.11)**
Melanoma	0.94 (0.76-1.16)	0.98 (0.79-1.22)	**1.25 (1.01-1.55)**	1.13 (0.90-1.42)
Soft tissue	0.90 (0.72-1.13)	0.93 (0.74-1.17)	0.95 (0.75-1.20)	1.03 (0.81-1.31)
Breast	1.00 (0.92-1.08)	**1.12 (1.03-1.21)**	1.08 (0.99-1.18)	**1.20 (1.10-1.31)**
Cervix	0.99 (0.83-1.17)	1.00 (0.83-1.19)	1.11 (0.93-1.32)	1.16 (0.96-1.39)
Corpus uteri	0.91 (0.78-1.07)	1.07 (0.91-1.25)	1.10 (0.93-1.29)	1.08 (0.91-1.28)
Ovary	**1.14 (1.02-1.26)**	**1.12 (1.01-1.25)**	**1.14 (1.02-1.27)**	**1.22 (1.09-1.37)**
Prostate	1.15 (1.00-1.33)	**1.41 (1.23-1.63)**	**1.43 (1.24-1.66)**	**1.62 (1.40-1.88)**
Testis	0.84 (0.40-1.76)	1.03 (0.49-2.17)	1.41 (0.71-2.81)	1.74 (0.86-3.51)
Kidney	0.94 (0.83-1.08)	0.99 (0.86-1.13)	1.06 (0.93-1.21)	1.02 (0.89-1.17)
Bladder	0.97 (0.89-1.06)	0.94 (0.86-1.02)	1.00 (0.92-1.10)	0.99 (0.91-1.09)
Brain	1.07 (0.98-1.17)	1.07 (0.97-1.17)	1.04 (0.94-1.14)	1.04 (0.94-1.15)
Thyroid	1.13 (0.75-1.70)	1.20 (0.80-1.82)	1.24 (0.83-1.85)	**1.58 (1.05-2.37)**
Hodgkin lymphoma	0.82 (0.55-1.21)	0.91 (0.61-1.34)	1.00 (0.67-1.51)	0.89 (0.58-1.37)
Non-Hodgkin lymphoma	1.01 (0.90-1.12)	**1.13 (1.02-1.26)**	1.05 (0.94-1.18)	**1.19 (1.06-1.33)**
Multiple myeloma	1.09 (0.96-1.25)	**1.20 (1.05-1.37)**	1.15 (1.00-1.32)	**1.23 (1.07-1.41)**
Leukemia	0.99 (0.90-1.10)	0.99 (0.90-1.10)	1.00 (0.90-1.11)	1.08 (0.96-1.20)
All cancer sites	1.01 (0.99-1.03)	**1.05 (1.03-1.07)**	**1.06 (1.04-1.08)**	**1.11 (1.09-1.13)**

[a]Reference: Q1 (least deprived); Abbreviations: GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases Version 10; Q, quintile.

Table 19 Relative excess risks for 5-year age-standardized relative survival in 2012-2014 by GIMD quintile and cancer site for cancer patients in Germany, adjusted for East/West Germany

	GIMD Quintiles Relative excess risk of 5-year relative survival (95 % Confidence Intervals)[a]			
Cancer site	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**
Oral	1.04 (0.95-1.14)	**1.16 (1.06-1.27)**	**1.19 (1.09-1.30)**	**1.30 (1.19-1.42)**
Esophagus	0.99 (0.90-1.09)	0.94 (0.85-1.03)	1.00 (0.90-1.10)	1.05 (0.95-1.15)
Stomach	0.98 (0.92-1.05)	1.00 (0.93-1.07)	1.03 (0.96-1.10)	1.06 (0.99-1.14)
Colon and rectum	**1.06 (1.01-1.11)**	**1.11 (1.06-1.16)**	**1.10 (1.05-1.16)**	**1.17 (1.11-1.23)**
Liver	1.03 (0.94-1.12)	**1.09 (1.00-1.19)**	**1.13 (1.03-1.23)**	**1.12 (1.02-1.22)**
Gallbladder	1.06 (0.95-1.19)	**1.14 (1.02-1.27)**	1.10 (0.98-1.23)	1.08 (0.97-1.22)
Pancreas	1.02 (0.96-1.08)	**1.08 (1.02-1.14)**	1.03 (0.97-1.10)	**1.09 (1.03-1.16)**
Larynx	1.19 (0.97-1.46)	1.01 (0.82-1.25)	**1.39 (1.14-1.70)**	**1.24 (1.01-1.52)**
Lung	1.00 (0.97-1.04)	**1.05 (1.02-1.09)**	**1.05 (1.02-1.09)**	**1.09 (1.05-1.13)**
Melanoma	0.91 (0.73-1.12)	0.95 (0.77-1.17)	1.21 (0.98-1.48)	1.12 (0.91-1.39)
Soft tissue	0.89 (0.71-1.10)	0.93 (0.75-1.16)	0.93 (0.74-1.17)	1.03 (0.83-1.30)
Breast	1.00 (0.92-1.08)	**1.12 (1.04-1.21)**	**1.09 (1.01-1.18)**	**1.21 (1.12-1.32)**
Cervix	0.99 (0.83-1.17)	1.01 (0.85-1.19)	1.11 (0.93-1.31)	1.12 (0.95-1.33)
Corpus uteri	0.91 (0.78-1.07)	1.06 (0.91-1.23)	1.10 (0.94-1.29)	1.08 (0.92-1.27)
Ovary	**1.18 (1.06-1.30)**	**1.16 (1.05-1.28)**	**1.18 (1.06-1.31)**	**1.30 (1.17-1.45)**
Prostate	**1.19 (1.03-1.37)**	**1.48 (1.29-1.70)**	**1.51 (1.31-1.74)**	**1.68 (1.46-1.93)**
Testis	0.92 (0.45-1.91)	0.98 (0.47-2.04)	1.42 (0.72-2.78)	1.88 (0.96-3.66)
Kidney	0.97 (0.85-1.10)	1.01 (0.89-1.14)	1.09 (0.96-1.24)	1.08 (0.95-1.23)
Bladder	1.00 (0.92-1.09)	0.96 (0.88-1.04)	1.03 (0.95-1.12)	1.01 (0.93-1.10)
Brain	1.07 (0.98-1.17)	1.08 (0.99-1.18)	1.04 (0.95-1.15)	1.05 (0.95-1.15)
Thyroid	1.19 (0.80-1.75)	1.35 (0.92-1.99)	1.40 (0.95-2.04)	**1.54 (1.05-2.26)**
Hodgkin lymphoma	0.81 (0.55-1.20)	0.92 (0.63-1.34)	1.01 (0.69-1.49)	0.85 (0.57-1.28)
Non-Hodgkin lymphoma	1.00 (0.90-1.12)	**1.13 (1.02-1.25)**	1.05 (0.94-1.17)	**1.19 (1.07-1.32)**
Multiple myeloma	1.07 (0.94-1.21)	**1.19 (1.05-1.35)**	1.11 (0.97-1.26)	**1.19 (1.04-1.35)**
Leukemia	0.98 (0.89-1.09)	1.00 (0.91-1.11)	1.01 (0.91-1.12)	1.08 (0.97-1.20)
All cancer sites	**1.03 (1.01-1.04)**	**1.07 (1.06-1.09)**	**1.08 (1.07-1.10)**	**1.13 (1.11-1.15)**

[a]Reference: Q1 (least deprived); Abbreviations: GIMD, German Index of Multiple Deprivation; ICD-10, International Classification of Diseases Version 10; Q, quintile.

Table 20 Five-year age-standardized relative survival by GIMD quintile and cancer site for cancer patients in Germany, period 2003-2005 and 2012-2014, including only registries providing data for all years of diagnosis 1998-2014

	Period 2003-2005				Period 2012-2014			
	5-year relative survival (standard error)			Relative excess risk (95 % confidence interval)[a]	5-year relative survival (standard error)			Relative excess risk (95 % confidence interval)[a]
Cancer site	Q1	Q5	Q1-Q5[b]	Q5 (most deprived)	Q1	Q5	Q1-Q5[b]	Q5 (most deprived)
Oral	44.1 (2.0)	43.3 (1.3)	0.8	**1.17 (1.02-1.34)**	49.7 (1.6)	46.1 (1.0)	3.6	**1.40 (1.21-1.62)**
Esophagus	19.5 (1.9)	15.4 (1.1)	4.1	**1.18 (1.00-1.38)**	25.2 (1.7)	21.1 (1.1)	4.1	1.15 (1.00-1.33)
Stomach	28.1 (1.2)	27.4 (0.7)	0.7	1.08 (0.98-1.19)	31.8 (1.2)	30.8 (0.8)	1.0	1.06 (0.96-1.18)
Colon and rectum	58.8 (0.7)	57.3 (0.5)	1.5	**1.19 (1.11-1.28)**	64.8 (0.6)	61.9 (0.4)	2.9	**1.22 (1.14-1.32)**
Liver	13.5 (1.6)	10.3 (1.0)	3.2	**1.22 (1.04-1.42)**	17.0 (1.7)	15.3 (1.0)	1.7	1.11 (0.97-1.27)
Gallbladder	17.3 (2.1)	16.4 (1.3)	0.9	1.09 (0.93-1.29)	30.7 (2.6)	21.6 (1.5)	9.1	**1.37 (1.14-1.64)**
Pancreas	9.2 (1.0)	7.6 (0.6)	1.6	**1.13 (1.01-1.25)**	14.7 (1.1)	11.4 (0.7)	3.3	**1.11 (1.01-1.21)**
Larynx	62.7 (3.4)	58.3 (2.2)	4.4	1.37 (0.98-1.92)	64.3 (2.8)	60.4 (1.9)	3.9	1.33 (0.96-1.85)
Lung	15.0 (0.5)	13.7 (0.4)	1.3	**1.13 (1.07-1.19)**	20.3 (0.6)	17.9 (0.4)	2.4	**1.10 (1.05-1.16)**
Melanoma	87.6 (1.1)	85.1 (0.8)	2.5	**1.95 (1.38-2.76)**	94.2 (0.7)	91.5 (0.5)	2.7	**2.07 (1.38-3.08)**
Soft tissue	57.3 (3.2)	56.3 (2.2)	1.0	0.96 (0.70-1.33)	68.3 (3.0)	68.2 (2.2)	0.1	0.95 (0.69-1.30)
Breast	80.1 (0.6)	79.6 (0.5)	0.5	**1.16 (1.03-1.30)**	84.2 (0.5)	83.5 (0.4)	0.7	**1.17 (1.03-1.32)**
Cervix	62.9 (2.3)	61.8 (1.3)	1.1	1.10 (0.83-1.46)	68.4 (2.2)	63.9 (1.4)	4.5	1.32 (0.99-1.75)
Corpus uteri	78.1 (1.5)	78.6 (0.9)	-0.5	0.93 (0.73-1.18)	79.0 (1.4)	78.6 (0.9)	0.4	1.06 (0.83-1.35)
Ovary	35.6 (1.5)	36.8 (1.0)	-1.2	1.15 (0.99-1.34)	42.2 (1.7)	37.5 (1.1)	4.7	**1.35 (1.15-1.60)**
Prostate	82.8 (1.0)	82.2 (0.7)	0.6	**1.49 (1.23-1.80)**	89.9 (1.0)	87.8 (0.7)	2.1	**1.84 (1.44-2.35)**
Testis	82.1 (2.0)	86.0 (3.0)	-3.9	**2.51 (1.05-5.99)**	90.8 (3.0)	89.5 (2.6)	1.3	2.80 (0.85-9.28)
Kidney	69.3 (1.5)	67.8 (0.9)	1.5	1.05 (0.88-1.25)	74.4 (1.3)	74.4 (0.8)	0.0	1.05 (0.87-1.26)
Bladder	50.7 (1.5)	56.1 (1.0)	-5.4	**0.86 (0.75-0.98)**	56.9 (1.3)	54.4 (0.9)	2.5	1.10 (0.97-1.25)
Brain	24.1 (1.7)	26.1 (1.2)	-2.0	**0.86 (0.74-0.99)**	31.3 (1.5)	31.0 (1.1)	0.3	1.09 (0.95-1.25)
Thyroid	87.9 (2.0)	86.9 (1.2)	1.0	**2.19 (1.00-4.79)**	91.7 (1.5)	88.1 (1.1)	3.6	**2.87 (1.31-6.27)**
Hodgkin lymphoma	81.5 (2.4)	81.3 (1.5)	0.2	1.90 (0.97-3.71)	85.9 (2.1)	84.7 (1.5)	1.2	1.21 (0.66-2.22)
Non-Hodgkin lymphoma	56.2 (1.5)	55.9 (1.0)	0.3	1.15 (0.99-1.35)	71.6 (1.2)	66.0 (0.8)	5.6	**1.59 (1.33-1.90)**
Multiple myeloma	40.9 (2.1)	37.6 (1.5)	3.3	**1.34 (1.10-1.65)**	56.9 (1.9)	51.4 (1.4)	5.5	**1.47 (1.19-1.82)**
Leukemia	45.3 (1.7)	49.1 (1.1)	-3.8	1.06 (0.90-1.25)	58.0 (1.5)	58.6 (1.0)	-0.6	1.05 (0.89-1.22)
All cancer sites[c]	53.9 (0.3)	53.3 (0.2)	0.6	**1.14 (1.11-1.17)**	60.4 (0.3)	58.0 (0.2)	2.4	**1.18 (1.15-1.22)**

[a]Reference: Q1 (least deprived), adjusted for age at diagnosis; [b]Difference of GIMD quintiles; [c]Analyses for all cancer sites combined are weighted (survival rates) or adjusted (relative excess risks) for case mix.

3.3 Analyses of data from the clinical cancer registries in Germany[7]

3.3.1 Lung cancer survival

Overall, 22,905 patients were included (Figure 4) of whom 47.1 % were registered in the clinical cancer registry located in Regensburg, 72.9 % were male, 23.8 % were over 75 years of age, 49.5 % had stage IV cancer, 45.3 % had a lung cancer of the upper lobe and 82.7 % had a NSCLC (Table 21). Chi-square tests revealed significant differences for all factors except subtype, however, there were only marginal differences for most factors when comparing across area-based socioeconomic deprivation groups (Table 21). Patients resident in most deprived municipalities were more often males, less often diagnosed with an adenocarcinoma, more often diagnosed with squamous cell carcinoma or SCLC and had more often undetermined grading. Within the catchment areas of registries, municipalities in the Dresden and Erfurt region were more deprived on average than municipalities in the Regensburg region (Table 21). Median time from diagnosis to first neoadjuvant or adjuvant treatment was 20, 21, 26, 24, and 23 days for Q1 (least deprived), Q2, Q3, Q4, and Q5 (most deprived), respectively.

For the total population, the number of observed deaths was 18,277 (79.8 %) and median follow-up time in months was 72.0 (69.0-73.0). Figure 14 shows non-standardized OS curves for the total study population stratified by stage and area-based deprivation quintiles. The corresponding one-, three-, and five-year OS rates are displayed in Table 22. For the total study population, survival was at each time point lowest for most deprived areas but no gradient across deprivation groups was observed (5-year survival difference to Q1: Q2 1.3 %, Q3 0.5 %, Q4 1.5 %, Q5 2.8 %, Figure 14, Table 22). In patients with stage I/II, survival was highest in the least deprived quintiles and in patients with stage III, survival was lowest in the most deprived quintile. There was no difference for other quintiles in these subgroups and no difference in patients with stage IV patients (Figure 14, Table 22).

[7]The different parts of this chapter are based on and were presented in the article Finke et al. 2020. The author's contribution to the different parts is declared in section 7.1.

Table 21 Characteristics of the total study population of lung cancer patients stratified by area-based socioeconomic deprivation quintiles

	Total	Deprivation quintile					
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)	p-value[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Cases	22,905 (100.0)	3,904 (17.0)	4,662 (20.4)	4,690 (20.5)	4,622 (20.2)	5,027 (22.0)	
Cancer Registry							
Dresden	6,752 (29.5)	551 (14.1)	1,730 (37.1)	1,722 (36.7)	794 (17.2)	1,955 (38.9)	
Erfurt	5,373 (23.5)	160 (4.1)	260 (5.6)	1,270 (27.1)	1,893 (41.0)	1,790 (35.6)	
Regensburg	10,780 (47.1)	3,193 (81.8)	2,672 (57.3)	1,698 (36.2)	1,935 (41.9)	1,282 (25.5)	<.0001
Sex							
Men	16,690 (72.9)	2,816 (72.1)	3,298 (70.7)	3,391 (72.3)	3,335 (72.2)	3,850 (76.6)	
Women	6,215 (27.1)	1,088 (27.9)	1,364 (29.3)	1,299 (27.7)	1,287 (27.8)	1,177 (23.4)	<.0001
Age at diagnosis (years)							
15-54	3,007 (13.1)	581 (14.9)	584 (12.5)	587 (12.5)	617 (13.3)	638 (12.7)	
55-59	2,508 (10.9)	467 (12.0)	475 (10.2)	512 (10.9)	516 (11.2)	538 (10.7)	
60-64	3,452 (15.1)	565 (14.5)	720 (15.4)	675 (14.4)	714 (15.4)	778 (15.5)	
65-69	4,099 (17.9)	710 (18.2)	831 (17.8)	828 (17.7)	831 (18.0)	899 (17.9)	
70-74	4,398 (19.2)	714 (18.3)	922 (19.8)	928 (19.8)	853 (18.5)	981 (19.5)	
75+	5,441 (23.8)	867 (22.2)	1,130 (24.2)	1,160 (24.7)	1,091 (23.6)	1,193 (23.7)	0.022
Mean (years ± SD)	67.2 ± 10.3	66.4 ± 10.4	67.5 ± 10.3	67.5 ± 10.3	67.1 ± 10.3	67.3 ± 10.2	
Period of Diagnosis							
2000-2010	14,769 (64.5)	2,383 (61.0)	2,873 (61.6)	3,107 (66.2)	2,982 (64.5)	3,424 (68.1)	
2011-2015	8,136 (35.5)	1,521 (39.0)	1,789 (38.4)	1,583 (33.8)	1,640 (35.5)	1,603 (31.9)	<.0001
Diagnosis (ICD-10)							
C34.0 Main bronchus	2,765 (12.1)	539 (13.8)	607 (13.0)	504 (10.7)	538 (11.6)	577 (11.5)	
C34.1 Upper lobe	10,375 (45.3)	1,730 (44.3)	2,155 (46.2)	2,150 (45.8)	2,097 (45.4)	2,243 (44.6)	
C34.2 Middle lobe	947 (4.1)	162 (4.1)	176 (3.8)	181 (3.9)	215 (4.7)	213 (4.2)	
C34.3 Lower lobe	5,591 (24.4)	925 (23.7)	1,139 (24.4)	1,153 (24.6)	1,125 (24.3)	1,249 (24.8)	
C34.8 Overlapping lesion	838 (3.7)	129 (3.3)	163 (3.5)	204 (4.3)	142 (3.1)	200 (4.0)	
C34.9 Unspecified	2,389 (10.4)	419 (10.7)	422 (9.1)	498 (10.6)	505 (10.9)	545 (10.8)	<.0001
Stage at diagnosis							
I	3,321 (16.2)	532 (15.3)	654 (15.5)	748 (18.0)	684 (16.9)	703 (15.5)	
II	1,625 (7.9)	298 (8.6)	319 (7.6)	323 (7.8)	328 (8.1)	357 (7.9)	
III	5,384 (26.3)	924 (26.6)	1,068 (25.3)	1,076 (25.9)	1,047 (25.9)	1,269 (28.0)	
IV	10,111 (49.5)	1,723 (49.6)	2,184 (51.7)	2,011 (48.4)	1,987 (49.1)	2,206 (48.6)	
Missing	2,464 (10.8)	427 (10.9)	437 (9.4)	532 (11.3)	576 (12.5)	492 (9.8)	0.003
Histological subtype							
NSCLC							
Adenocarcinoma	6,912 (30.2)	1,243 (31.9)	1,566 (33.6)	1,405 (30.0)	1,345 (29.1)	1,353 (26.9)	
Squamous cell carcinoma	7,081 (31.0)	1,165 (29.9)	1,389 (29.8)	1,403 (30.0)	1,419 (30.7)	1,705 (34.0)	
Other	4,910 (21.5)	803 (20.6)	897 (19.3)	1,091 (23.3)	1,063 (23.0)	1,056 (21.0)	
SCLC[3]	3,975 (17.4)	685 (17.6)	807 (17.3)	785 (16.8)	791 (17.1)	907 (18.1)	
Missing	27 (0.1)	8 (0.2)	3 (0.1)	6 (0.1)	4 (0.1)	6 (0.1)	0.522[b]
Grading							
Low/intermediate grade	7,168 (41.1)	1,313 (47.9)	1,475 (45.7)	1,470 (40.3)	1,346 (35.6)	1,564 (38.9)	
High grade	7,158 (41.1)	1,319 (48.1)	1,572 (48.7)	1,427 (39.1)	1,476 (39.1)	1,364 (33.9)	
Undetermined	3,094 (17.8)	109 (4.0)	180 (5.6)	751 (20.6)	961 (25.4)	1,093 (27.2)	
Missing	5,485 (23.9)	1,163 (29.8)	1,435 (30.8)	1,042 (22.2)	839 (18.2)	1,006 (20.0)	<.0001
Chemotherapy	10,819 (50.6)	2,065 (54.5)	2,123 (48.7)	2,141 (49.8)	2,083 (48.2)	2,407 (52.3)	NA
Radiotherapy	6,928 (30.2)	1,060 (27.2)	1,396 (29.9)	1,450 (30.9)	1,376 (29.8)	1,646 (32.7)	NA
Surgery	5,752 (25.1)	990 (25.4)	1,100 (23.6)	1,227 (26.2)	1,207 (26.1)	1,228 (24.4)	NA

Abbreviations: ICD, International Classification of Diseases; N, number of observations; NA, not applicable; NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer; SD, standard deviation; [3]N=12 patients had an additional diagnosis of NSCLC; [a]P-value from Chi-square test comparing the distribution of the factors and deprivation quintiles; [b]Comparing NSCLC and SCLC.

Pre-defined multivariable models for the total study population consistently showed a statistically significantly lower survival in the most deprived quintile (HR 1.06, 9 5% CI 1.01-1.11, Figure 15, Table 23). Adjusting for cancer registry attenuated the association (Table 23). Stratified analyses showed lower survival in the most deprived municipalities for patients with stage I/II (HR 1.13, 95 % CI 1.00-1.28) and stage III (1.13, 1.03-1.24) lung cancer but no gradient across area-based deprivation quintiles (Figure 15, Table 23). Medium-sized differences in survival were observed between the most and least deprived municipalities for these subgroups and no difference for patients with stage IV lung cancer (stage I+II: 2.2-4.1 % units, stage III: 3.0-4.0 % units, Figure 15 and Table A4, Appendix). When adjusting for cancer registry, effect estimates were slightly larger in the subgroup diagnosed with stage I/II (Table 23). Stratified analyses by patient and tumor factors revealed lower survival in the most deprived municipalities for men, age group 15-69 years, low/intermediate grade, NSCLC, period of diagnosis 2011-2015, and follow-up length of 1 year and 5 years (Table 24). A significant trend towards lower survival in the most deprived areas in subgroups with overall better prognosis was observed (Tables 23 and 24).

Table 22 Kaplan-Meier estimates stratified by area-based socioeconomic deprivation and by stage at diagnosis for the total population of lung cancer patients registered in three German clinical cancer registries.

Area-based socioeconomic deprivation quintile	**Overall Survival in % (95 % Confidence Interval)**		
	1 year	**3 years**	**5 years**
Total population			
Q1 (=least deprived)	48.8 (47.2-50.4)	22.6 (21.1-24.0)	17.2 (15.8-18.5)
Q2	47.7 (46.2-49.2)	22.0 (20.7-23.3)	15.9 (14.8-17.2)
Q3	47.9 (46.5-49.4)	23.5 (22.2-24.8)	16.7 (15.5-17.9)
Q4	47.7 (46.2-49.1)	22.6 (21.3-23.9)	15.7 (14.5-16.9)
Q5 (=most deprived)	**46.6 (45.2-48.0)**	**20.7 (19.6-22.0)**	**14.4 (13.3-15.5)**
Stage I + II			
Q1 (=least deprived)	81.3 (78.4-83.9)	59.0 (55.3-62.5)	48.1 (44.2-51.9)
Q2	80.2 (77.4-82.7)	58.3 (54.9-61.5)	46.9 (43.4-50.4)
Q3	79.3 (76.7-81.7)	55.3 (52.2-58.4)	42.9 (39.7-46.2)
Q4	**76.8 (74.0-79.3)**	52.8 (49.5-55.9)	**40.1 (36.8-43.4)**
Q5 (=most deprived)	78.3 (75.6-80.7)	**52.5 (49.3-55.6)**	40.7 (37.5-43.9)
Stage III			
Q1 (=least deprived)	53.7 (50.3-56.9)	21.1 (18.4-23.9)	15.2 (12.8-17.8)
Q2	54.2 (51.2-57.2)	18.8 (16.4-21.3)	12.0 (10.0-14.2)
Q3	52.5 (49.4-55.4)	20.9 (18.4-23.4)	14.2 (12.0-16.6)
Q4	53.6 (50.5-56.5)	20.7 (18.3-23.2)	13.5 (11.4-15.8)
Q5 (=most deprived)	**47.9 (45.1-50.7)**	**17.7 (15.6-19.9)**	**10.9 (9.2-12.8)**
Stage IV			
Q1 (=least deprived)	30.6 (28.4-32.8)	**6.2 (5.0-7.5)**	3.7 (2.8-4.9)
Q2	29.4 (27.5-31.4)	7.1 (6.0-8.4)	3.9 (3.0-5.0)
Q3	**28.9 (26.9-30.9)**	8.1 (6.9-9.4)	4.3 (3.4-5.4)
Q4	29.3 (27.3-31.3)	7.8 (6.6-9.2)	4.0 (3.0-5.2)
Q5 (=most deprived)	30.3 (28.4-32.3)	7.0 (5.9-8.2)	**3.6 (2.8-4.6)**

Lowest overall survival among the quintiles is printed in bold.

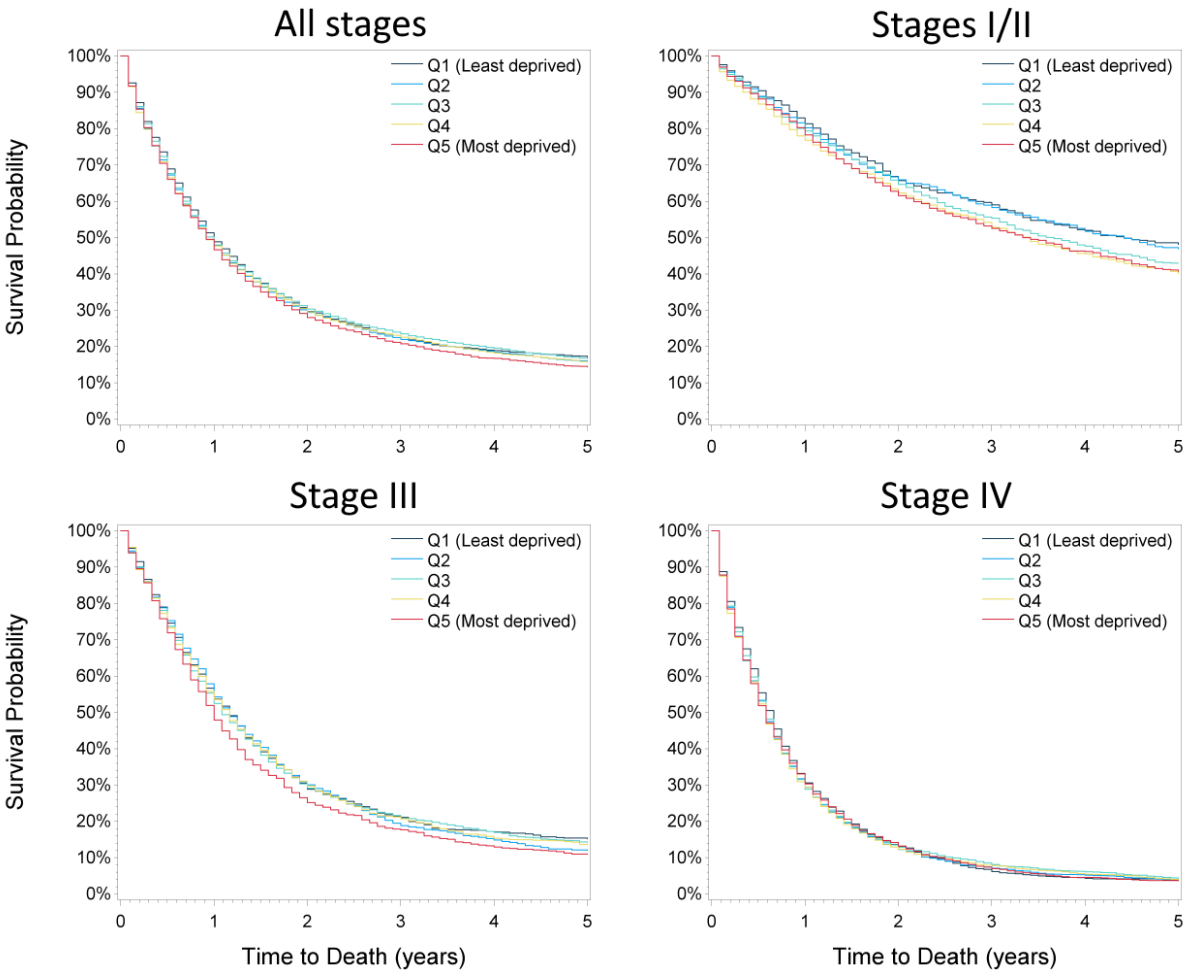

Figure 14 Kaplan Meier curves stratified by area-based socioeconomic deprivation and by stage at diagnosis for the total population of lung cancer patients registered in three German clinical cancer registries.

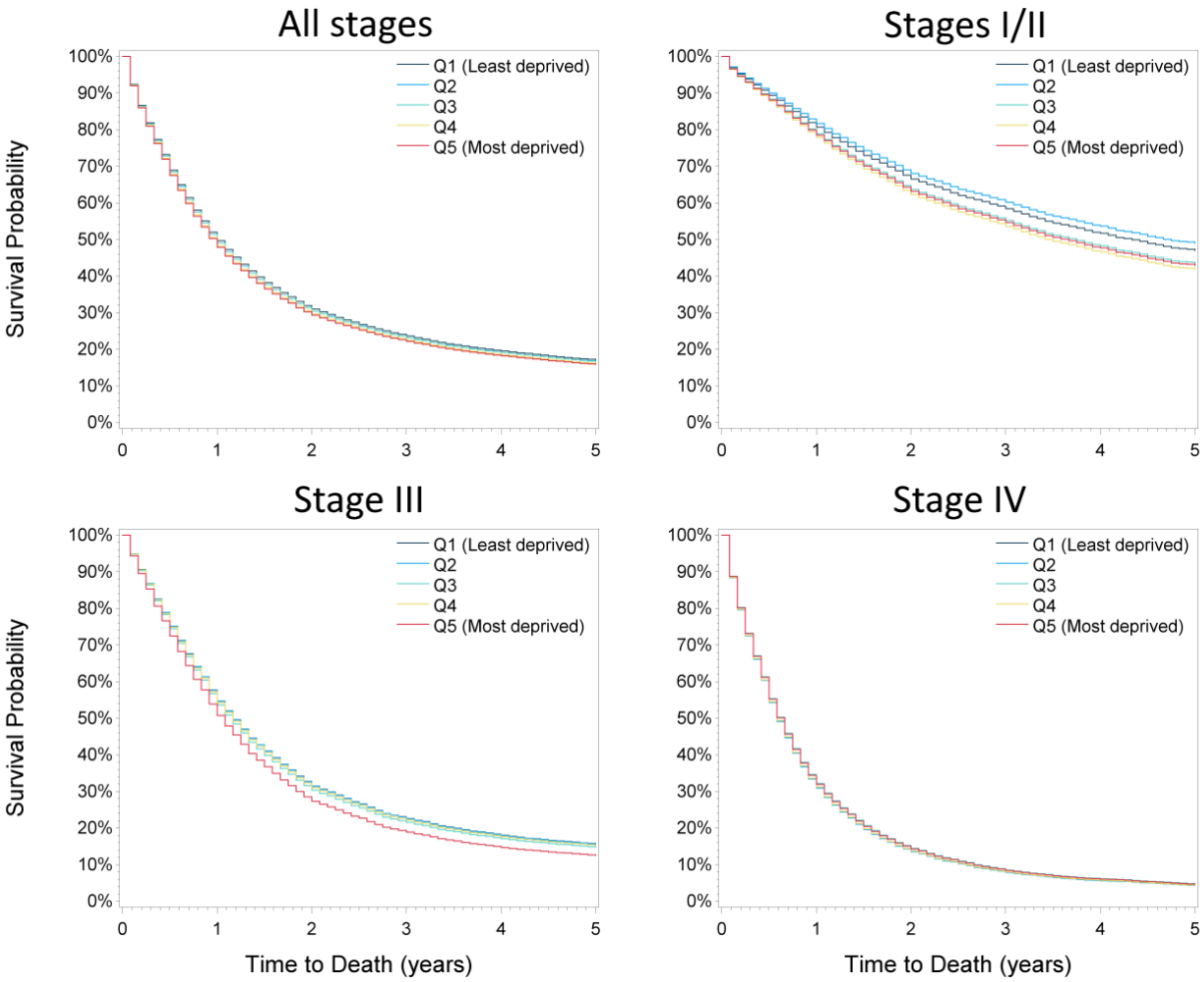

Figure 15 Adjusted survival curves stratified by area-based socioeconomic deprivation and by stage at diagnosis for the total population of lung cancer patients registered in three German clinical cancer registries.

Table 23 Association between area-based socioeconomic deprivation and lung cancer survival overall and stratified by stage at diagnosis with different levels of adjustment.

Subgroup (deprivation quintile)	Events N (%)	Model Hazard ratio (95% confidence interval)*			Adjusted 5-year survival rate %[c]	Model 3 plus cancer registry[d] Hazard ratio (95% confidence interval)*
		Model 1[a]	Model 2[b]	Model 3[c]		
Total population	18,277 (79.8)					
Q1 (Least deprived)		1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	17.1 (16.2-18.0)	1.00 (ref.)
Q2		1.02 (0.97-1.07)	1.02 (0.97-1.07)	1.02 (0.97-1.07)	16.7 (15.9-17.5)	1.00 (0.96-1.06)
Q3		1.00 (0.95-1.05)	1.01 (0.96-1.06)	1.02 (0.97-1.07)	16.7 (15.9-17.5)	1.00 (0.95-1.05)
Q4		1.03 (0.98-1.08)	1.03 (0.98-1.08)	1.05 (1.00-1.10)	16.1 (15.3-17.0)	1.02 (0.97-1.08)
Q5 (Most deprived)		**1.06 (1.01-1.11)**	**1.06 (1.01-1.11)**	**1.06 (1.01-1.11)**	15.9 (15.1-16.7)	1.03 (0.98-1.08)
Stage I/II	3,182 (56.8)					
Q1 (Least deprived)		1.00 (ref.)	1.00 (ref.)		47.0 (43.7-50.2)	1.00 (ref.)
Q2		0.93 (0.82-1.06)	0.94 (0.83-1.07)		49.0 (45.9-51.9)	0.97 (0.85-1.10)
Q3		1.10 (0.97-1.24)	1.11 (0.98-1.26)		43.5 (40.7-46.3)	**1.14 (1.00-1.30)**
Q4		**1.16 (1.03-1.31)**	**1.17 (1.04-1.32)**		41.8 (38.9-44.6)	**1.19 (1.05-1.35)**
Q5 (Most deprived)		1.12 (0.99-1.26)	**1.13 (1.00-1.28)**		42.9 (40.0-45.6)	**1.17 (1.03-1.32)**
Stage III	4,978 (82.3)					
Q1 (Least deprived)		1.00 (ref.)	1.00 (ref.)		15.6 (13.6-17.8)	1.00 (ref.)
Q2		1.00 (0.91-1.10)	1.00 (0.91-1.10)		15.6 (13.7-17.6)	1.00 (0.91-1.10)
Q3		1.03 (0.94-1.13)	1.03 (0.94-1.14)		14.8 (12.9-16.7)	1.02 (0.92-1.12)
Q4		1.02 (0.93-1.12)	1.01 (0.92-1.12)		15.3 (13.4-17.3)	0.99 (0.90-1.10)
Q5 (Most deprived)		**1.13 (1.03-1.23)**	**1.13 (1.03-1.24)**		12.6 (11.0-14.2)	**1.11 (1.00-1.22)**
Stage IV	10,117 (89.9)					
Q1 (Least deprived)		1.00 (ref.)	1.00 (ref.)		4.7 (3.9-5.6)	1.00 (ref.)
Q2		1.03 (0.97-1.11)	1.03 (0.96-1.10)		4.3 (3.6-5.0)	1.01 (0.94-1.08)
Q3		1.00 (0.93-1.07)	1.00 (0.93-1.06)		4.8 (4.1-5.6)	0.96 (0.89-1.03)
Q4		1.03 (0.97-1.10)	1.02 (0.96-1.10)		4.4 (3.7-5.2)	0.99 (0.93-1.06)
Q5 (Most deprived)		1.01 (0.94-1.07)	1.00 (0.94-1.07)		4.7 (4.0-5.4)	0.96 (0.89-1.03)

Abbreviations: N, number of events; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years), sex (males, females) and year of diagnosis. [b]Same adjustment as model 1 plus cancer subtype (NSCLC, SCLC) and grading (well- or moderately differentiated, poorly or undifferentiated). [c]Same adjustment as model 2 plus stage at diagnosis (I, II, III, IV). In stage stratified analyses, this is the same model as model 2. [d]Same adjustment as model 3 plus registry (Dresden, Erfurt, Regensburg). *Hazard ratios with p<0.05 are printed in bold;

Patients receiving surgery showed a lower survival when resident in the more deprived municipalities (Q4: HR 1.13. 95 % CI 1.00-1.27, Table 24). This association strengthened for Q4, when further restricting to patients with stages I-III for whom surgery is indicated according to German recommendations (Q4: 1.19, 1.05-1.36, Supplementary Table 25). Further restriction to patients receiving chemotherapy or radiotherapy changed effect estimates which were not statistically significant. However, CIs were large for these subgroups (Tables 24 and 25).

Table 26 shows the association of the area-specific socioeconomic deprivation quintiles with survival within each region. In neither region, significant differences between the least and most deprived areas were observed. Survival was significantly lower than in Q1 in Erfurt city but not in Dresden city.

The sensitivity analysis for the Cox models including an additional category for Dresden city revealed similar results for deprivation quintiles compared to the main analysis (Table 23, 24, and Table A5, Appendix). Dresden city had significantly lower survival in subgroups with high grading and SCLC and better survival in subgroups receiving chemotherapy or surgery compared to the least deprived municipalities (Table A5, Appendix).

The sensitivity analysis for treatment groups using follow-up start 30, 60, and 90 days after diagnosis showed marginal differences to the main analysis (Table 24 and Table A6, Appendix).

Table 24 Association between area-based socioeconomic deprivation and lung cancer survival stratified by patient and tumor characteristics with full adjustment.

Subgroup	Events N (%)	Deprivation quintile Hazard ratio (95% confidence interval)*[a]					Deprivation quintile Adjusted 5-year survival rate %[a]	
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)	Q1 (Least deprived)	Q5 (Most deprived)
Men	13,677 (82.0)	1.00 (ref.)	1.03 (0.97-1.09)	1.03 (0.98-1.09)	1.06 (1.00-1.12)	**1.08 (1.02-1.14)**	15.7 (14.7-16.7)	14.1 (13.3-15.0)
Women	4,600 (74.0)	1.00 (ref.)	0.98 (0.89-1.08)	0.96 (0.87-1.06)	1.01 (0.91-1.11)	0.99 (0.90-1.10)	20.7 (18.9-22.5)	20.8 (19.1-22.6)
Age 15-69 years	10,136 (77.6)	1.00 (ref.)	0.98 (0.92-1.05)	0.98 (0.92-1.05)	1.02 (0.96-1.09)	**1.07 (1.00-1.14)**	19.7 (18.5-20.9)	18.3 (17.3-19.4)
Age 70+ years	8,141 (82.7)	1.00 (ref.)	1.07 (0.99-1.15)	**1.08 (1.00-1.16)**	**1.09 (1.01-1.17)**	1.06 (0.99-1.14)	13.3 (12.1-14.7)	12.7 (11.6-13.8)
Low/intermediate grade	18,277 (79.8)	1.00 (ref.)	1.00 (0.92-1.08)	1.00 (0.93-1.09)	1.08 (1.00-1.18)	**1.09 (1.00-1.18)**	23.1 (21.5-24.7)	21.1 (19.6-22.5)
High grade	10,558 (83.4)	1.00 (ref.)	1.03 (0.96-1.10)	1.03 (0.96-1.10)	1.02 (0.95-1.09)	1.04 (0.97-1.11)	12.4 (11.3-13.5)	11.7 (10.8-12.8)
NSCLC	14,756 (78.0)	1.00 (ref.)	1.02 (0.97-1.08)	1.01 (0.95-1.06)	1.05 (0.99-1.11)	**1.06 (1.00-1.12)**	19.1 (18.1-20.1)	17.8 (16.9-18.7)
SCLC	3,521 (88.5)	1.00 (ref.)	1.02 (0.91-1.14)	1.08 (0.97-1.21)	1.03 (0.92-1.16)	1.07 (0.96-1.19)	8.2 (6.7-9.8)	7.2 (6.0-8.5)
Period 2000-2010	13,228 (89.6)	1.00 (ref.)	1.01 (0.95-1.07)	1.02 (0.96-1.08)	1.03 (0.97-1.09)	1.03 (0.98-1.09)	16.0 (15.0-17.0)	15.4 (14.5-16.2)
Period 2011-2015	5,049 (62.1)	1.00 (ref.)	1.04 (0.95-1.13)	1.01 (0.92-1.11)	1.09 (0.99-1.19)	**1.12 (1.03-1.23)**	n/a[§]	n/a[§]
Chemotherapy	9,759 (84.3)	1.00 (ref.)	0.96 (0.90-1.02)	0.95 (0.89-1.02)	0.96 (0.90-1.02)	0.97 (0.91-1.03)	11.1 (10.1-12.2)	11.7 (10.8-12.8)
Radiotherapy	5,733 (82.8)	1.00 (ref.)	1.02 (0.94-1.12)	0.98 (0.90-1.07)	0.97 (0.89-1.07)	1.05 (0.96-1.14)	15.1 (13.4-17.0)	14.0 (12.6-15.6)
Surgery	3,121 (54.3)	1.00 (ref.)	0.95 (0.84-1.08)	1.08 (0.96-1.21)	**1.13 (1.00-1.27)**	1.10 (0.98-1.24)	49.5 (46.4-52.5)	46.5 (43.8-49.1)
FU length: 3 months	4,385 (19.1)	1.00 (ref.)	1.09 (0.99-1.20)	1.03 (0.94-1.14)	**1.13 (1.02-1.25)**	1.09 (0.99-1.21)	n/a[§]	n/a[§]
FU length: 1 year	11,510 (50.3)	1.00 (ref.)	1.03 (0.97-1.10)	1.04 (0.98-1.11)	**1.06 (1.00-1.13)**	**1.06 (1.00-1.13)**	n/a[§]	n/a[§]
FU length: 3 years	16,452 (71.8)	1.00 (ref.)	1.03 (0.98-1.08)	1.02 (0.97-1.07)	1.04 (0.99-1.10)	1.05 (1.00-1.10)	n/a[§]	n/a[§]
FU length: 5 years	17,420 (76.1)	1.00 (ref.)	1.04 (0.98-1.09)	1.03 (0.98-1.08)	**1.06 (1.00-1.11)**	**1.06 (1.01-1.11)**	17.7 (16.8-18.6)	16.4 (15.6-17.2)

Abbreviations: FU, follow-up; N, number of events; n/a, not applicable; NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years), sex (males, females), year of diagnosis, cancer subtype (NSCLC, SCLC), grading (well- or moderately differentiated, poorly or undifferentiated) and stage at diagnosis (I, II, III, IV). *Hazard ratios with p<0.05 are printed in bold; [§]No 5-year survival rates available, as follow-up time is below 5 years

Table 25 Association between area-based socioeconomic deprivation and lung cancer survival among patients with stage I-III cancer, overall and among patients with specific therapies.

Subgroup	Events N (%)	Deprivation quintile Hazard ratio (95% confidence interval)[a]*				
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)
Stage I-III	8,160 (70.1)	1.00 (ref.)	0.99 (0.92-1.07)	**1.08 (1.00-1.16)**	**1.08 (1.00-1.16)**	**1.14 (1.06-1.22)**
Stage I-III + surgery	2,618 (51.4)	1.00 (ref.)	0.93 (0.81-1.07)	1.12 (0.99-1.27)	**1.19 (1.05-1.36)**	1.11 (0.98-1.26)
Stage I-III + surgery + chemotherapy	937 (58.2)	1.00 (ref.)	1.01 (0.81-1.27)	1.17 (0.95-1.44)	1.20 (0.96-1.49)	1.20 (0.97-1.48)
Stage I-III + surgery + radiotherapy	690 (67.3)	1.00 (ref.)	0.96 (0.73-1.27)	0.98 (0.76-1.27)	1.11 (0.86-1.43)	1.01 (0.78-1.31)

N, number of events; *Hazard ratios with p<0.05 are printed in bold; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years) and sex (males, females), year of diagnosis, cancer subtype (NSCLC, SCLC), grading (well- or moderately differentiated, poorly or undifferentiated), and stage at diagnosis (I, II, III).

Table 26 Association between region-specific area-based socioeconomic deprivation and lung cancer survival stratified by three German clinical cancer registries.

Registry	Events N (%)	Deprivation quintile Hazard ratio (95% confidence interval)[a,]*					
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)	Dresden/Erfurt city[b]
Dresden	5,470 (81.0)	1.00 (ref.)	0.94 (0.83-1.05)	1.00 (0.89-1.12)	0.91 (0.82-1.02)	1.09 (0.98-1.21)	0.94 (0.85-1.03)
Erfurt	4,344 (80.9)	1.00 (ref.)	1.10 (0.97-1.25)	1.11 (0.98-1.26)	1.08 (0.95-1.22)	1.11 (0.98-1.26)	**1.15 (1.04-1.29)**
Regensburg	8,463 (78.5)	1.00 (ref.)	0.97 (0.90-1.04)	1.01 (0.94-1.08)	0.98 (0.92-1.06)	0.99 (0.92-1.06)	-

Abbreviations: N, number of events; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years) and sex (males, females), year of diagnosis, cancer subtype (NSCLC, SCLC), grading (well- or moderately differentiated, poorly or undifferentiated), stage at diagnosis (I, II, III, IV); [b]For the cancer registry Dresden and Erfurt, the cities Dresden and Erfurt were classified separately, as they would otherwise dominate the classification of the quintiles. The deprivation value for Dresden lies between Q1 and Q2 in 2006 and in Q2 in 2010. For Erfurt, it lies in Q1 in 2006 and in Q2 in 2010; *Hazard ratios with p<0.05 are printed in bold

3.3.2 Breast cancer survival

In total, 31,357 patients were included in the analysis (Table 27, Figure 5). Chi-square tests showed significant differences across GIMD quintiles for the distribution of all factors except tumor side and grading (Table 27). However, comparing the relative frequencies across the GIMD quintiles, these differences were rather small, except for cancer registry. Patients resident in least deprived municipalities were slightly younger and more often diagnosed in the most recent period of diagnosis 2012-2016 compared to all other patients. Most patients were diagnosed with stage I and II breast cancer. Around 96 % of the patients received hormone therapy, half of the patients received chemotherapy, more than 60 % received radiotherapy and the vast majority received surgery (Table 27). There was a small gradual increase in receiving chemotherapy from the least to the most deprived quintile but no clear relation for hormone therapy and surgery.

Figure 16 shows RS rates for the period 2011-2016 stratified by GIMD quintiles. Survival differences between deprivation quintiles were more pronounced in later follow-up years. Five-year RS was slightly lower for the most compared to the least deprived regions (RS and standard error; Q5: 79.5 % (1.0) vs. Q1: 82.0 % (0.9); Table 28), but the difference did not reach statistical significance in model-based analysis. The corresponding RER for the most compared to the least deprived regions was 1.14 (CI 0.98-1.33). There was no gradual increase or decrease in RS across GIMD quintiles. RS was highest in the third quintile, which included mainly the large city of Dresden (84.4 % (0.9).

Stage-stratified RS are shown in Figure 17 and Table 28. RS was lowest for the most deprived quintiles in stage I (93.6 (1.8) vs. 98.1 % (1.4)) and stage II (84.5 (1.6) vs. 88.4 % (1.5)). However, standard errors were generally wide. Consequently, model-based analyses showed no significant RERs for any deprivation quintiles (compared to the most affluent quintile) except for Q3 and Q4 in stage III (Table 28).

Table 27 Characteristics of the total study population of breast cancer patients stratified by area-based socioeconomic deprivation quintile

Characteristic[a]	Total	Deprivation quintile					p-value[b]
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)	
	N (%)	N (%)	N (%)	N (%)	N (%)	N (%)	
Cases	31,357 (100.0)	6,365 (20.3)	6,596 (21.0)	6,447 (20.6)	5,909 (18.8)	6.040 (19.3)	
Cancer Registry							
Dresden	9,588 (30.6)	841 (13.2)	2,070 (31.4)	3,123 (48.4)	905 (15.3)	2,649 (43.9)	
Erfurt	5,585 (17.8)	123 (1.9)	387 (5.9)	936 (14.5)	2,222 (37.6)	1,917 (31.7)	
Regensburg	16,184 (51.6)	5,401 (84.9)	4,139 (62.8)	2,388 (37.0)	2,782 (47.1)	1,474 (24.4)	<0.0001
Age at diagnosis (years)							
15-44	2,954 (9.4)	682 (10.7)	637 (9.7)	612 (9.5)	535 (9.1)	488 (8.1)	
45-54	6,466 (20.6)	1,406 (22.1)	1,354 (20.5)	1,322 (20.5)	1,168 (19.8)	1,216 (20.1)	
55-64	7,006 (22.3)	1,451 (22.8)	1,491 (22.6)	1,365 (21.2)	1,323 (22.4)	1,376 (22.8)	
65-74	7,763 (24.8)	1,482 (23.3)	1,586 (24.0)	1,653 (25.6)	1,525 (25.8)	1,517 (25.1)	
75+	7,168 (22.9)	1,344 (21.1)	1,528 (23.2)	1,495 (23.2)	1,358 (23.0)	1,443 (23.9)	<0.0001
Mean (years ± SD)	63.4 (13.8)	62.5 (13.8)	63.5 (14.0)	63.6 (13.9)	63.8 (13.7)	63.9 (13.5)	
Period of Diagnosis							
2006-2011	16,890 (53.9)	3,264 (51.3)	3,472 (52.6)	3,391 (52.6)	3,353 (56.7)	3,410 (56.5)	
2012-2016	14,467 (46.1)	3,101 (48.7)	3,124 (47.4)	3,056 (47.4)	2,556 (43.3)	2,630 (43.5)	<0.0001
Diagnosis (ICD-10)							
C50.0	334 (1.1)	74 (1.2)	88 (1.3)	57 (0.9)	65 (1.1)	50 (0.8)	
C50.1	1,418 (4.5)	242 (3.8)	275 (4.2)	313 (4.9)	275 (4.7)	313 (5.2)	
C50.2	3,297 (10.5)	695 (10.9)	687 (10.4)	740 (11.5)	603 (10.2)	572 (9.5)	
C50.3	1,711 (5.5)	351 (5.5)	367 (5.6)	339 (5.3)	304 (5.1)	350 (5.8)	
C50.4	11,103 (35.4)	2,121 (33.3)	2,279 (34.6)	2,420 (37.5)	2,100 (35.5)	2,183 (36.1)	
C50.5	2,483 (7.9)	471 (7.4)	501 (7.6)	532 (8.3)	457 (7.7)	522 (8.6)	
C50.6	69 (0.2)	13 (0.2)	10 (0.2)	21 (0.3)	11 (0.2)	14 (0.2)	
C50.8	6,007 (19.2)	1,480 (23.3)	1,469 (22.3)	1,206 (18.7)	831 (14.1)	1,021 (16.9)	
C50.9	4,935 (15.7)	918 (14.4)	920 (13.9)	819 (12.7)	1,263 (21.4)	1,015 (16.8)	<0.0001
Side of the body							
Both sides	843 (2.7)	163 (2.6)	176 (2.7)	186 (2.9)	166 (2.8)	152 (2.5)	
Left	15,838 (50.5)	3,258 (51.2)	3,278 (49.7)	3,243 (50.3)	3,006 (50.9)	3,053 (50.5)	
Right	14,676 (46.8)	2,944 (46.3)	3,142 (47.6)	3,018 (46.8)	2,737 (46.3)	2,835 (46.9)	0.69
Stage at diagnosis							
I	12,224 (41.9)	2,317 (39.6)	2,558 (41.9)	2,689 (44.2)	2,280 (42.0)	2,380 (41.9)	
II	10,548 (36.2)	2,148 (36.7)	2,213 (36.2)	2,148 (35.3)	1,954 (36.0)	2,085 (36.7)	
III	4,157 (14.3)	871 (14.9)	869 (14.2)	834 (13.7)	785 (14.4)	798 (14.1)	
IV	2,231 (7.7)	513 (8.8)	471 (7.7)	419 (6.9)	415 (7.6)	413 (7.3)	0.0003
Grading							
Low grade	4,152 (13.8)	824 (13.6)	883 (13.9)	905 (14.5)	788 (13.8)	752 (12.9)	
Intermediate grade	18,178 (60.3)	3,669 (60.6)	3,804 (60)	3,751 (60.2)	3,381 (59.2)	3,573 (61.2)	
High grade	7,838 (26.0)	1,562 (25.8)	1,648 (26.0)	1,575 (25.3)	1,544 (27.0)	1,509 (25.9)	0.16
Estrogen receptor status							
Negative	4,429 (15.4)	854 (14.7)	906 (14.7)	924 (15.2)	875 (16.3)	870 (16.1)	
Positive	24,417 (84.6)	4,968 (85.3)	5,271 (85.3)	5,161 (84.8)	4,477 (83.7)	4,540 (83.9)	0.03
Hormone therapy	21,421 (96.3)	4,428 (94.7)	4,734 (96.0)	4,964 (97.2)	3,123 (95.3)	4,172 (98.2)	NA
Chemotherapy	14,516 (46.3)	2,834 (44.5)	2,846 (43.1)	2,933 (45.5)	2,974 (50.3)	2,929 (48.5)	NA
Radiotherapy	19,818 (63.2)	4,133 (64.9)	4,169 (63.2)	4,171 (64.7)	3,566 (60.3)	3,779 (62.6)	NA
Surgery							
No	140 (0.5)	48 (0.9)	53 (0.9)	11 (0.2)	23 (0.4)	5 (0.1)	
Yes	28,442 (99.5)	5,597 (99.1)	5,892 (99.1)	5,887 (99.8)	5,426 (99.6)	5,640 (99.9)	<0.0001

Abbreviations: ICD, International Classification of Diseases; N, number of observations; NA, not applicable SD, standard deviation; [a]Number (proportion) of missing/undetermined values: Stage at diagnosis: 2,197 (7.0 %); Grading: 1,189 (3.8 %); Estrogen receptor status: 2,511 (8.0 %); Surgery: 2,775 (8.8 %); [b]P-value from Chi-square test comparing the distribution of the factors and deprivation quintiles;

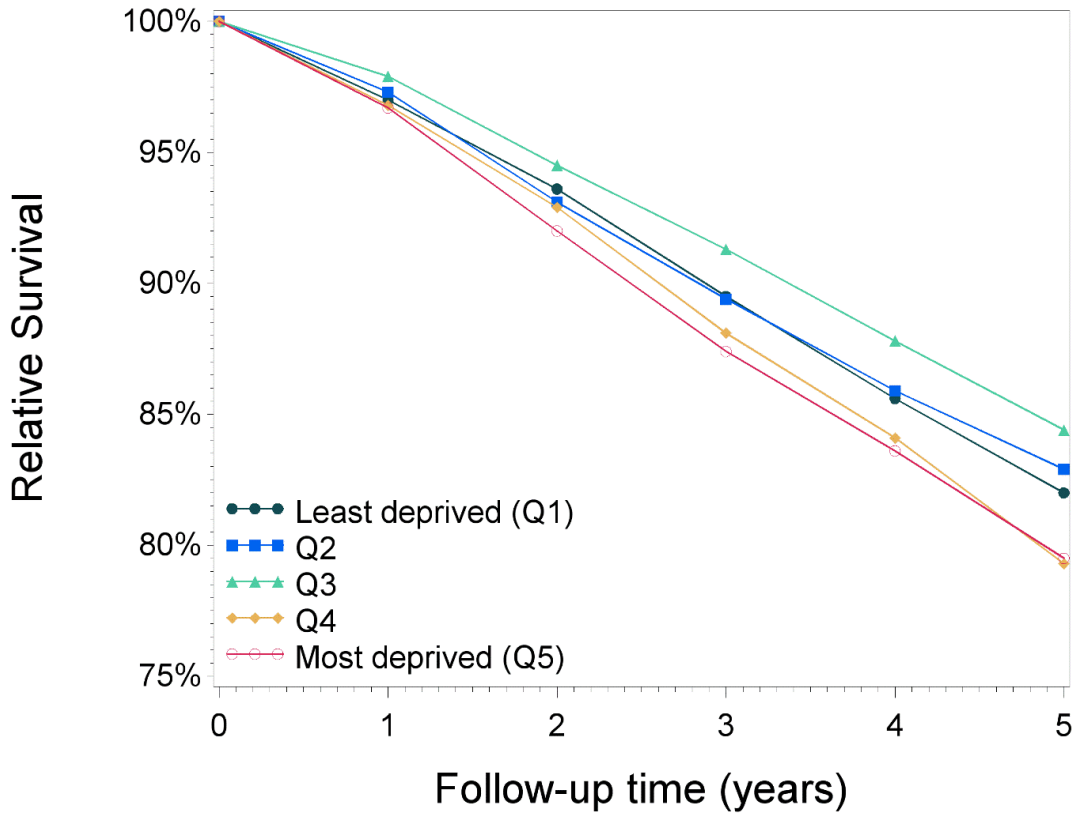

Figure 16 Relative survival of breast cancer patients registered in three German clinical cancer registries for the period 2011-2016 stratified by area-based socioeconomic deprivation quintiles

Table 28 Five-year relative survival rates for breast cancer patients for the period 2011-2016 and relative excess risks by area-based socioeconomic deprivation quintiles

Subgroup	Measure[b]	Deprivation quintiles[a]				
		Q1 (least deprived)	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**
Total	RS	82.0 (0.9)	82.9 (0.9)	84.4 (0.9)	79.3 (1.0)	79.5 (1.0)
	RER[c]	1.00 (ref.)	0.95 (0.82-1.10)	0.86 (0.74-1.00)	1.11 (0.96-1.29)	1.14 (0.98-1.33)
Stage I	RS	98.1 (1.4)	98.9 (1.5)	98.6 (1.3)	94.7 (1.9)	93.6 (1.8)
	RER[c]	1.00 (ref.)	0.53 (0.22-1.32)	0.81 (0.39-1.68)	1.05 (0.49-2.25)	1.48 (0.75-2.94)
Stage II	RS	88.4 (1.5)	89.6 (1.4)	91.4 (1.4)	87.5 (1.7)	84.5 (1.6)
	RER[c]	1.00 (ref.)	0.99 (0.71-1.38)	0.80 (0.56-1.14)	1.03 (0.72-1.47)	1.27 (0.91-1.77)
Stage III	RS	72.9 (2.5)	70.5 (2.5)	66.3 (2.6)	64.8 (2.9)	68.2 (2.8)
	RER[c]	1.00 (ref.)	1.18 (0.89-1.58)	**1.44 (1.09-1.90)**	**1.49 (1.12-1.99)**	1.32 (0.98-1.78)
Stage IV	RS	27.3 (3.0)	29.4 (3.0)	24.2 (3.2)	25.6 (3.2)	24.5 (3.5)
	RER[c]	1.00 (ref.)	0.96 (0.78-1.19)	1.01 (0.82-1.25)	1.03 (0.83-1.29)	1.07 (0.85-1.34)

Abbreviations: Q, quintile; RER, relative excess risk; RS, relative survival. [a]Relative excess risks with p<0.05 are printed in bold; [b]RS: 5-year relative survival in % (standard error); RER: Relative excess risk for 5-year relative survival (95 % confidence interval) compared to the least deprived group (Q1); [c]Adjusted for age and follow-up year.

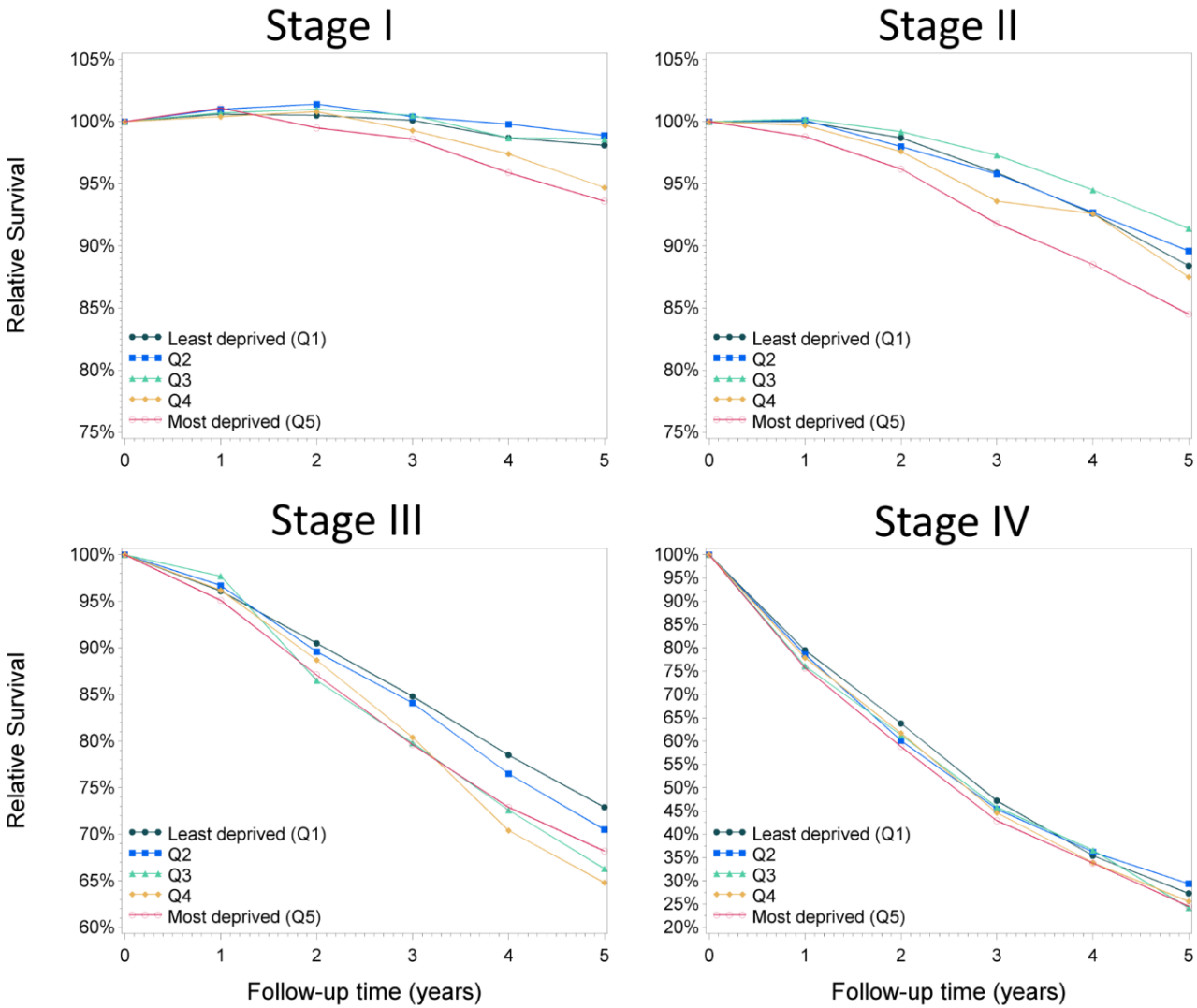

Figure 17 Relative survival of breast cancer patients registered in three German clinical cancer registries for the period 2011-2016 stratified by area-based socioeconomic deprivation quintiles and stage at diagnosis. Ordinate scales are reduced to different ranges.

Table 29 shows the change in RERs for 5-year RS with different levels of adjustment. The RER for the most deprived quintile was significant after adjustment for stage (RER 1.20 (95 % CI 1.02-1.40)). Further adjustment for grading and ER status attenuated the association and it lost significance (1.16 (0.98-1.37)). The association was completely resolved when additionally adjusting for cancer registry (0.94 (0.78-1.13)). In this model, RS was lower in the catchment areas of the Dresden and Erfurt registries compared with the Regensburg registry. This was still present when repeating the analyses without adjusting for the GIMD quintiles. The comparisons of the other quintiles (Q2-Q4) with the most affluent quintile did not show significant differences in any analyses.

Table 30 shows subgroup analyses by stage, ER status and treatment for models including both GIMD quintiles and region as well as models separately including GIMD or region. When adjusting for region, no significant association was found between the GIMD quintiles and RS. Compared to the Regensburg region, RS was lower in the Erfurt region in all subgroups. Differences were most pronounced for patients with stage I-III ER positive cancers. RS was lower in the Dresden region for stage I-III breast cancer patients in total and when restricted to patients who received radiotherapy and to ER positive patients who received hormone therapy, respectively. These associations were present in both models including or excluding the GIMD quintiles.

As Dresden city had a very large population size compared to all other municipalities, model-based analyses for the most recent calendar period were repeated in sensitivity analyses. Results were overall comparable, the city of Dresden had significantly better RS compared to the least deprived regions (Table 31).

Table 32 shows the 5-year RS and RER estimates separately for each cancer registry using the same deprivation quintiles as in the main analyses. No significant association between deprivation and RS was observed in any registry. In general, RS was lowest in the cancer registry Erfurt and similar in the registries Dresden and Regensburg. In the Dresden cancer registry, RS was lowest for the most and second most deprived quintiles and highest in Q3, which was driven by the city of Dresden. In the Erfurt cancer registry, RS was only estimable for Q3 to Q5 and was in all quintiles lower than the RS estimates in any quintile of the other two registries. No consistent pattern was observed for Regensburg.

Table 29 Five- year relative excess risk for deprivation quintile for breast cancer patients for the period 2011-2016 with different levels of adjustment

Model/Subgroup	RER for region	Deprivation quintiles 5-year relative excess risk (confidence interval)[a] Q1 (least deprived)	Q2	Q3	Q4	Q5 (most deprived)
Adjustment: age+ FU		1.00 (ref.)	0.95 (0.82-1.10)	0.86 (0.74-1.00)	1.11 (0.96-1.29)	1.14 (0.98-1.33)
+ stage		1.00 (ref.)	1.01 (0.88-1.18)	1.07 (0.92-1.24)	1.15 (0.99-1.34)	**1.20 (1.02-1.40)**
+ grading + ER		1.00 (ref.)	1.01 (0.87-1.18)	1.09 (0.93-1.27)	1.08 (0.92-1.28)	1.16 (0.98-1.37)
+ cancer registry		1.00 (ref.)	0.96 (0.82-1.13)	0.96 (0.81-1.13)	0.93 (0.78-1.12)	0.94 (0.78-1.13)
Dresden	**1.24 (1.09-1.42)**					
Erfurt	**1.51 (1.28-1.78)**					
Regensburg	1.00 (ref.)					
+ cancer registry (without GIMD)[b]						
Dresden	**1.22 (1.08-1.37)**					
Erfurt	**1.47 (1.27-1.70)**					
Regensburg	1.00 (ref.)					

Abbreviations: FU, follow-up year; ER, estrogen receptor status; Q, quintile; RER, relative excess risk. [a]Relative excess risks with p<0.05 are printed in bold; [b]Same model as before but without GIMD quintiles;

Table 30 Five- year relative excess risk by deprivation quintile and by region for breast cancer patients for the period 2011-2016 with and without adjustment for region and after stratification by treatment

Municipality characteristic		5- year relative excess risk (confidence interval)[a]									
		Stage I-III[b]		Stage I-III + chemotherapy[b,c]		Stage I-III + radiotherapy[b,c]		Stage I-III ER positive[d]		Stage I-III ER positive + hormone therapy[c,d]	
		Adjusted for region		Adjusted for region		Adjusted for region		Adjusted for region		Adjusted for region	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Deprivation	Q1 (least)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)	1.00 (ref.)
	Q2	1.05 (0.85-1.31)	0.99 (0.79-1.23)	1.18 (0.86-1.60)	1.11 (0.81-1.53)	0.97 (0.72-1.30)	0.92 (0.68-1.24)	0.89 (0.68-1.17)	0.83 (0.62-1.10)	0.87 (0.64-1.20)	0.79 (0.57-1.09)
	Q3	1.13 (0.91-1.40)	0.96 (0.76-1.21)	1.22 (0.90-1.64)	1.04 (0.75-1.45)	1.04 (0.77-1.39)	0.87 (0.63-1.20)	0.98 (0.74-1.28)	0.84 (0.63-1.12)	0.99 (0.72-1.35)	0.80 (0.57-1.11)
	Q4	1.13 (0.90-1.42)	0.89 (0.69-1.13)	1.24 (0.91-1.69)	0.98 (0.70-1.38)	0.99 (0.72-1.35)	0.82 (0.59-1.14)	1.07 (0.81-1.43)	0.80 (0.59-1.08)	0.93 (0.65-1.34)	0.72 (0.49-1.06)
	Q5 (most)	1.20 (0.96-1.51)	0.94 (0.73-1.20)	**1.37 (1.01-1.86)**	1.08 (0.77-1.52)	1.29 (0.96-1.74)	1.04 (0.75-1.43)	1.09 (0.82-1.44)	0.79 (0.58-1.08)	1.16 (0.84-1.60)	0.80 (0.56-1.14)
Region	Regensburg		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)
	Dresden		**1.23 (1.04-1.47)**		1.20 (0.94-1.53)		**1.28 (1.02-1.62)**		1.22 (0.98-1.52)		**1.44 (1.13-1.85)**
	Erfurt		**1.87 (1.52-2.30)**		**1.81 (1.36-2.41)**		**1.86 (1.38-2.50)**		**2.44 (1.88-3.16)**		**2.70 (1.92-3.82)**
Region only (no GIMD)	Regensburg		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)		1.00 (ref.)
	Dresden		**1.20 (1.02-1.41)**		1.22 (0.98-1.51)		**1.25 (1.01-1.54)**		1.14 (0.93-1.40)		**1.33 (1.06-1.67)**
	Erfurt		**1.77 (1.48-2.13)**		**1.84 (1.45-2.34)**		**1.81 (1.40-2.34)**		**2.22 (1.77-2.80)**		**2.44 (1.79-3.32)**

Abbreviations: ER, estrogen receptor status; Q, quintile. [a]Relative excess risks with p<0.05 are printed in bold; [b]Adjusted for age, follow-up year, stage, grading, ER; [c]Only patients who received their first therapy within one year after diagnosis; [d]Adjusted for age, follow-up year, stage, grading

Table 31 Relative excess risk for 5-year relative survival in breast cancer patients registered in three German clinical cancer registries for the period 2011-2016 stratified by area-based socioeconomic deprivation quintiles, with Dresden city as additional category

	Deprivation quintiles 5-year relative excess risk (confidence interval)[a]					
Model/ Subgroup	**Q1 (least deprived)**	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**	**Dresden city**
Adjustment: age+ FU	1.00 (ref.)	1.02 (0.88-1.18)	1.07 (0.90-1.27)	1.11 (0.96-1.29)	1.14 (0.98-1.32)	**0.65 (0.54-0.79)**
+ stage	1.00 (ref.)	1.04 (0.89-1.21)	1.08 (0.91-1.29)	1.15 (0.99-1.34)	**1.19 (1.02-1.39)**	0.99 (0.83-1.18)
+ grading + ER	1.00 (ref.)	1.00 (0.84-1.18)	0.99 (0.81-1.21)	0.97 (0.81-1.15)	1.06 (0.89-1.26)	**0.63 (0.51-0.78)**
Subgroups 1[b]						
Stage I-III	1.00 (ref.)	1.05 (0.82-1.34)	1.14 (0.88-1.49)	1.16 (0.92-1.47)	**1.27 (1.01-1.60)**	**0.69 (0.52-0.92)**
Stage I-III + chemotherapy[c]	1.00 (ref.)	1.15 (0.83-1.59)	1.36 (0.97-1.91)	1.15 (0.85-1.57)	1.23 (0.90-1.67)	**0.69 (0.48-0.99)**
Stage I-III + radiotherapy[c]	1.00 (ref.)	0.91 (0.65-1.27)	1.12 (0.80-1.57)	0.96 (0.69-1.32)	1.32 (0.98-1.77)	**0.56 (0.38-0.84)**
Subgroups 2[d]						
Stage I-III + ER positive	1.00 (ref.)	0.95 (0.70-1.30)	1.05 (0.75-1.46)	1.06 (0.78-1.43)	1.22 (0.91-1.63)	**0.55 (0.37-0.82)**
Stage I-III + ER positive + hormone therapy[c]	1.00 (ref.)	1.00 (0.70-1.42)	1.13 (0.78-1.65)	0.88 (0.60-1.31)	1.33 (0.96-1.84)	**0.59 (0.39-0.89)**

Abbreviations: FU, follow-up year; ER, estrogen receptor status; Q, quintile. [a]Relative excess risks with p<0.05 are printed in bold; [b]Adjusted for age, follow-up year, stage, grading, ER; [c]Only patients who received their first therapy within one year after diagnosis; [d]Adjusted for age, follow-up year, stage, grading

Table 32 Five-year relative survival rates for breast cancer patients for the period 2011-2016 and relative excess risks by area-based socioeconomic deprivation quintiles for each cancer registry

			Deprivation quintiles[a]				
Subgroup	**Measure[b]**	**Total region**	**Q1 (least deprived)**	**Q2**	**Q3**	**Q4**	**Q5 (most deprived)**
Dresden	RS	83.5 (0.8)	83.4 (2.7)	82.6 (1.9)	86.1 (1.2)	79.0 (2.9)	79.3 (1.6)
	RER[c]	-	1.00 (ref.)	0.95 (0.65-1.39)	0.80 (0.56-1.14)	1.16 (0.75-1.80)	1.23 (0.86-1.74)
Erfurt	RS	74.8 (1.2)	-[d]	-[d]	70.4 (3.3)	73.1 (2.0)	76.1 (2.1)
	RER[c]	-	1.00 (ref.)	2.67 (0.55-12.95)	2.66 (0.56-12.53)	2.49 (0.53-11.62)	2.34 (0.50-10.93)
Regensburg	RS	82.6 (0.6)	81.8 (1.0)	82.6 (1.1)	85.3 (1.5)	81.8 (1.4)	81.4 (2.2)
	RER[c]	-	1.00 (ref.)	0.95 (0.81-1.12)	0.83 (0.67-1.03)	0.96 (0.79-1.16)	0.95 (0.73-1.24)

Abbreviations: GIMD, German Index of Multiple Deprivation; Q, quintile; RER, relative excess risk; RS, relative survival. [a]Relative excess risks with p<0.05 are printed in bold; [b]RS: 5-year relative survival in % (standard error) ; RER: Relative excess risk for 5-year relative survival (95 % confidence interval) compared to the least deprived group (Q1); [c]Adjusted for age and follow-up year; [d]Relative survival estimates with a standard error larger than 5 are not shown.

3.4 Analysis of data from the Finnish cancer registry[8]

In total, 24 462 CRC patients were included in the analysis. Tables 33, 34 and Table A7 (Appendix) show the number and proportion of patients diagnosed in 2007–2016 stratified by sex and individual or area-based education level, respectively. Compared to men, women were more frequently represented in the basic education group which also had marginally more often unknown stage (Table 33). Patients with basic education were older and more often resident in rural or semi-urban municipalities compared to more educated patients (Table 33). In comparison with other hospital districts, there were more high educated patients resident in the capital (Helsinki) and less high educated patients resident in sparsely populated districts (Keski-Pohjanmaa, Kainuu, and Pohjois-Karjala; Table 34). Almost one third of the patients were resident in a municipality categorized in the low educational quartile Q1 (Table A7, Appendix). The mean proportion of basic educated residents per quartile were 34.6 % (Q1), 28.1 % (Q2), 24.7 % (Q3), and 21.0 % (Q4), respectively. Most high educated patients were resident in municipalities categorized into Q3 or Q4 (Table 35). Within sex strata, incidence rates (ASR) were highest in basic educated men and women with secondary education (Table 33). Among hospital districts, ASR ranged from 49.6 to 115.4 per 100 000 residents (Table A8, Appendix).

Survival

Median OS was 58, 78, and 87 months for basic, secondary and high educated CRC patients, respectively. There was a gradient across individual education levels for 5-year RS with clear differences between basic and high education (men: 6.9 % units, women: 9.5 % units; Table 36). The gradient was more consistent across follow-up time for women than for men (Figures 18A and B). Differences and gradients were still present when stratifying by cancer site (colon, men: 7.8 % units, women: 9.6 % units; rectum, men: 5.9 % units, women: 9.6 % units; Table 36). For area-based education, there was no gradient across quartiles and no clear difference for men (Table 36, Figure 18C and D). In women, the lowest education quartile had the lowest survival (Table 36, Figure 18D).

[8]The different parts of this chapter are based on and were presented in the article Finke, Seppä et al. 2021. The author's contribution to the different parts is declared in section 7.1.

Table 33 Number of colorectal cancer patients diagnosed in Finland in 2007-2016, stratified by sex, individual education, site, age, stage and urbanity.

	Men, N (%)[a]			Women, N (%)[a]		
	Basic	**Secondary**	**High**	**Basic**	**Secondary**	**High**
Number of cases (%)	7362 (48.6)	4165 (27.5)	3634 (24.0)	7218 (51.9)	3820 (27.5)	2860 (20.6)
Age-standardized incidence rate	80.4	79.6	78.6	67.9	69.3	68.5
Cancer site						
Colon	4361 (49.0)	2363 (26.5)	2184 (24.5)	5059 (53.1)	2539 (26.7)	1924 (20.2)
Rectum, rectosigmoid	3001 (48.0)	1802 (28.8)	1450 (23.2)	2159 (49.3)	1281 (29.3)	936 (21.4)
Age group						
25-44	65 (16.9)	177 (46.0)	143 (37.1)	48 (11.6)	161 (38.9)	205 (49.5)
45-54	206 (20.8)	456 (46.0)	330 (33.3)	140 (13.4)	485 (46.5)	418 (40.1)
55-64	1088 (33.5)	1283 (39.5)	878 (27.0)	695 (28.9)	933 (38.8)	777 (32.3)
65-74	2364 (47.0)	1382 (27.5)	1280 (25.5)	1747 (48.6)	1086 (30.2)	759 (21.1)
75+	3639 (66.1)	867 (15.7)	1003 (18.2)	4588 (71.2)	1155 (17.9)	701 (10.9)
Stage at diagnosis						
Unknown	1764 (48.6)	995 (27.4)	873 (24.0)	1868 (52.8)	981 (27.7)	692 (19.5)
Local	2035 (47.3)	1198 (27.9)	1065 (24.8)	1924 (51.9)	1000 (27.0)	781 (21.1)
Non-local	3563 (49.3)	1972 (27.3)	1696 (23.5)	3426 (51.5)	1839 (27.6)	1387 (20.9)
Urban/rural area						
Urban municipality	4237 (43.5)	2665 (27.4)	2840 (29.2)	4491 (48.7)	2555 (27.7)	2181 (23.6)
Semi-urban municipality	1456 (54.8)	755 (28.4)	444 (16.7)	1302 (55.9)	640 (27.5)	386 (16.6)
Rural municipality	1669 (60.4)	745 (27.0)	350 (12.7)	1425 (60.8)	625 (26.7)	293 (12.5)

Abbreviations: N, number of observations; SD, standard deviation. [a]Percentages refer to distribution of education by sex.

Table 34 Number and proportion of patients diagnosed with colorectal cancer in Finland in 2007-2016, stratified by sex, individual education and hospital district.

	Men, N (row %)[a]			Women, N (row %)[a]		
Hospital district	**Basic**	**Secondary**	**High**	**Basic**	**Secondary**	**High**
Karjala	241 (56.6)	97 (22.8)	88 (20.7)	232 (57.0)	110 (27.0)	65 (16.0)
Etelä-Pohjanmaa	343 (56.8)	155 (25.7)	106 (17.5)	308 (54.8)	161 (28.6)	93 (16.5)
Etelä-Savo	189 (53.7)	96 (27.3)	67 (19.0)	218 (59.4)	102 (27.8)	47 (12.8)
Helsinki	483 (35.6)	314 (23.2)	558 (41.2)	641 (42.8)	358 (23.9)	498 (33.3)
Itä-Savo	70 (52.2)	40 (29.9)	24 (17.9)	59 (50.4)	36 (30.8)	22 (18.8)
Kainuu	109 (52.4)	56 (26.9)	43 (20.7)	99 (55.6)	52 (29.2)	27 (15.2)
Kanta-Häme	261 (44.5)	191 (32.5)	135 (23.0)	263 (54.8)	134 (27.9)	83 (17.3)
Keski-Pohjanmaa	110 (54.2)	65 (32.0)	28 (13.8)	109 (55.3)	56 (28.4)	32 (16.2)
Keski-Suomi	366 (51.0)	202 (28.1)	150 (20.9)	363 (55.0)	182 (27.6)	115 (17.4)
Kymenlaakso	339 (49.5)	198 (28.9)	148 (21.6)	312 (53.5)	177 (30.4)	94 (16.1)
Lappi	153 (49.7)	90 (29.2)	65 (21.1)	137 (51.3)	85 (31.8)	45 (16.9)
Länsi-Pohja	101 (52.6)	57 (29.7)	34 (17.7)	82 (51.6)	42 (26.4)	35 (22.0)
Pirkanmaa	700 (47.4)	457 (30.9)	321 (21.7)	710 (53.0)	382 (28.5)	247 (18.4)
Pohjois-Karjala	274 (54.2)	149 (29.4)	83 (16.4)	215 (52.4)	126 (30.7)	69 (16.8)
Pohjois-Pohjanmaa	402 (50.2)	218 (27.2)	181 (22.6)	405 (52.3)	225 (29.1)	144 (18.6)
Pohjois-Savo	369 (52.4)	199 (28.3)	136 (19.3)	307 (48.8)	202 (32.1)	120 (19.1)
Päijät-Häme	403 (54.8)	178 (24.2)	154 (21.0)	355 (57.8)	161 (26.2)	98 (16.0)
Satakunta	392 (51.9)	227 (30.1)	136 (18.0)	388 (57.1)	169 (24.9)	122 (18.0)
Uusimaa	970 (43.1)	587 (26.1)	694 (30.8)	948 (46.5)	564 (27.7)	525 (25.8)
Vaasa	323 (53.5)	164 (27.2)	117 (19.4)	302 (58.8)	121 (23.5)	91 (17.7)
Varsinais-Suomi	719 (49.4)	398 (27.3)	339 (23.3)	723 (53.8)	346 (25.7)	275 (20.5)
Åland	45 (45.5)	27 (27.3)	27 (27.3)	42 (50.0)	29 (34.5)	13 (15.5)

Abbreviations: N, number of observations; SD, standard deviation. [a]Percentages refer to sex-specific distribution of individual education within hospital districts.

Table 35 Cross tabulation of individual and area-based education for colorectal cancer patients diagnosed in Finland in 2007-2016.

		Individual Education					
		Men, N (row %)[a]			Women, N (row %)[a]		
		Basic	Secondary	High	Basic	Secondary	High
Area-based Education	Q1 (low)	2899 (39.4)	1324 (31.8)	732 (20.1)	2546 (35.3)	1136 (29.7)	586 (20.5)
	Q2	1814 (24.6)	1120 (26.9)	898 (24.7)	1860 (25.8)	987 (25.8)	637 (22.3)
	Q3	1392 (18.9)	869 (20.9)	1068 (29.4)	1587 (22.0)	879 (23.0)	899 (31.4)
	Q4 (high)	1257 (17.1)	852 (20.5)	936 (25.8)	1225 (17.0)	818 (21.4)	738 (25.8)

Abbreviations: N, number of observations. [a]Percentages refer to sex-specific distribution of individual education within hospital districts.

Table 36 Five-year age-standardized relative survival in 2012-2016 by individual and area-based education and sex for colorectal cancer patients in Finland.

	5-year Relative Survival (95 % Confidence Interval)	
	Men	Women
Individual Education		
Colorectal		
Basic	61.8 (59.6-64.0)	61.2 (59.0-63.5)
Secondary	64.3 (61.2-67.5)	67.2 (64.2-70.3)
High	68.7 (65.7-71.8)	70.7 (67.2-74.5)
Colon		
Basic	61.2 (58.4-64.1)	59.4 (56.7-62.2)
Secondary	62.8 (58.7-67.2)	66.7 (62.9-70.6)
High	69.0 (65.0-73.1)	69.0 (64.6-73.6)
Rectum		
Basic	62.3 (59.1-65.7)	64.6 (60.8-68.7)
Secondary	65.9 (61.5-70.7)	68.3 (63.5-73.3)
High	68.2 (63.7-73.0)	74.2 (68.3-80.6)
Area-based Education		
Colorectal		
Q1 (low)	63.9 (61.4-66.5)	60.4 (57.8-63.1)
Q2	64.7 (61.8-67.7)	66.5 (63.7-69.5)
Q3	64.4 (61.3-67.6)	69.1 (66.1-72.2)
Q4 (high)	62.4 (59.2-65.9)	64.9 (61.7-68.3)
Colon		
Q1 (low)	63.9 (60.5-67.4)	58.1 (55.0-61.5)
Q2	65.1 (61.3-69.2)	64.8 (61.3-68.4)
Q3	63.5 (59.4-67.8)	69.0 (65.4-72.9)
Q4 (high)	61.4 (57.1-66.0)	64.7 (60.8-68.8)
Rectum, rectosigmoid		
Q1 (low)	63.6 (59.9-67.5)	64.8 (60.6-69.3)
Q2	63.8 (59.7-68.3)	70.6 (65.7-75.8)
Q3	65.9 (61.3-70.9)	69.5 (64.5-74.8)
Q4 (high)	63.7 (58.9-69.0)	65.4 (60.0-71.3)

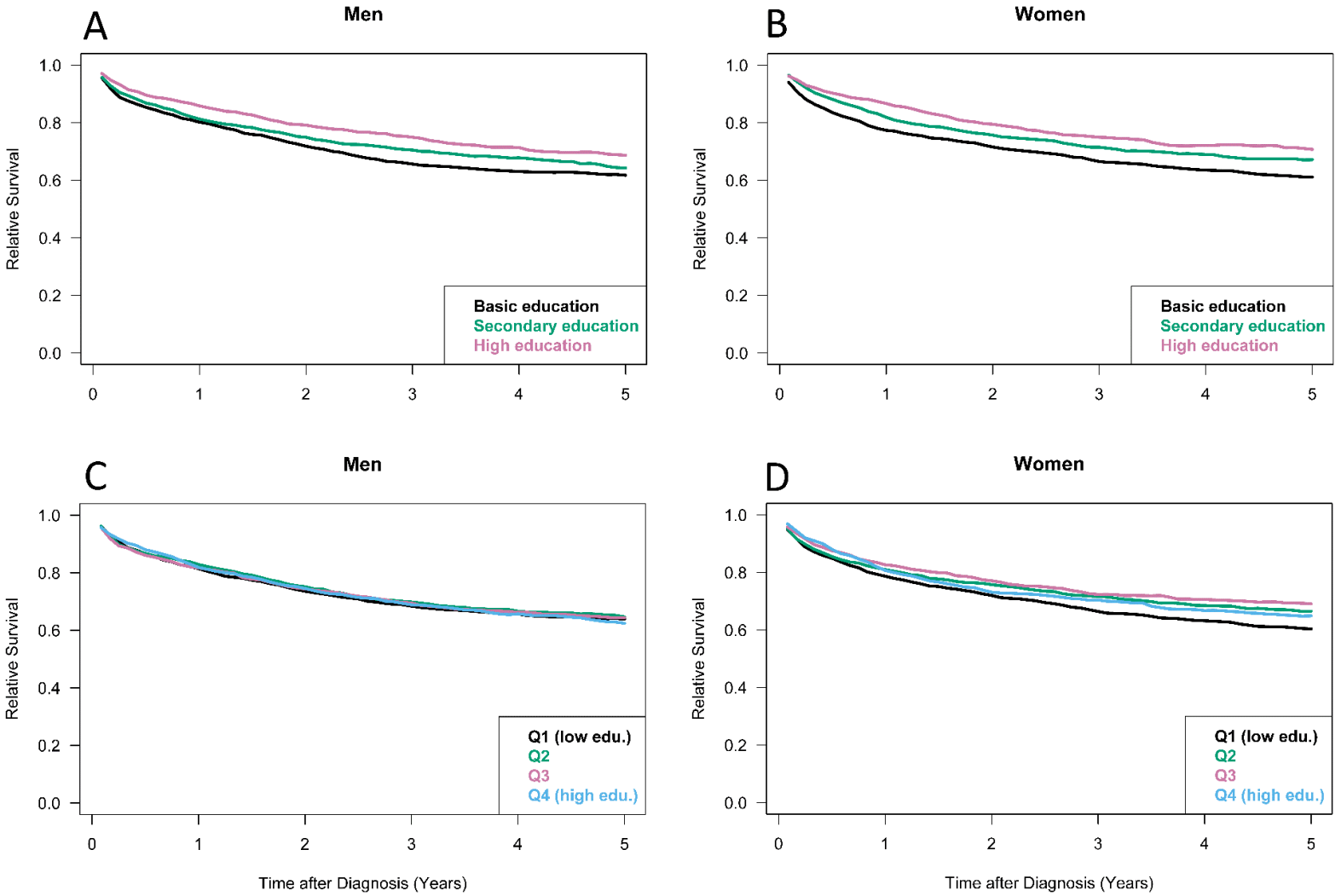

Figure 18 Age-standardized relative survival of colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016 by education and sex. A Individual education, men; B Individual education, women; C Area-based education, men; D Area-based education, women.

Relative excess risk

Table 37 shows RERs for models including both individual and area-based education, Table 38 shows the same models including either individual or area-based education. Results were similar irrespective of the model including both education measures or models only including individual or area-based education separately (Tables 37 and 38). Compared to the reference group of low educated patients, the secondary or high educated group showed a lower risk of death in both men and women (Table 38). Adjusting for hospital district and municipality had a small effect on the differences between education groups. Adjusting for stage decreased the differences. Further adjustment for cancer site and urbanity changed estimates by 0.01 to 0.02. Regarding area-based education, RER were attenuated and revealed associations only in women. Including region, stage, cancer site and urbanity in the models had little impact on the estimates (Tables 37 and 38).

Table 37 Relative excess risk of death (95% posterior interval) between education groups (basic and Q1 as reference) for colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016.

	Relative Excess Risk (95% posterior interval)				
		Adjusted for			
	Basic model	**Region**	**Region + stage**	**Region + stage + cancer site**	**Region + stage + cancer site + urbanity**
Men					
Individual Education					
Secondary	**0.86 (0.78-0.96)**	**0.86 (0.78-0.96)**	0.90 (0.81-1.00)	0.90 (0.81-1.00)	0.90 (0.81-1.00)
High	**0.72 (0.64-0.81)**	**0.73 (0.65-0.82)**	**0.77 (0.68-0.86)**	**0.77 (0.68-0.86)**	**0.76 (0.68-0.85)**
Area-based education					
Q2	0.99 (0.89-1.11)	1.00 (0.88-1.14)	1.04 (0.92-1.18)	1.04 (0.92-1.18)	0.98 (0.84-1.13)
Q3	1.03 (0.91-1.16)	1.05 (0.91-1.21)	1.04 (0.90-1.19)	1.03 (0.89-1.19)	0.97 (0.82-1.14)
Q4 (high)	1.02 (0.90-1.16)	1.01 (0.88-1.16)	1.02 (0.89-1.17)	1.02 (0.89-1.16)	0.94 (0.79-1.11)
Women					
Individual Education					
Secondary	**0.80 (0.67-0.96)**	**0.81 (0.72-0.90)**	**0.82 (0.73-0.91)**	**0.82 (0.73-0.91)**	**0.82 (0.73-0.91)**
High	**0.76 (0.59-0.96)**	**0.68 (0.59-0.78)**	**0.70 (0.61-0.80)**	**0.70 (0.61-0.80)**	**0.70 (0.61-0.80)**
Area-based education					
Q2	**0.82 (0.70-0.96)**	**0.82 (0.71-0.95)**	**0.85 (0.73-0.98)**	**0.84 (0.72-0.97)**	**0.82 (0.69-0.98)**
Q3	0.87 (0.74-1.02)	**0.80 (0.67-0.95)**	**0.78 (0.65-0.94)**	**0.78 (0.64-0.93)**	**0.76 (0.62-0.93)**
Q4 (high)	0.87 (0.73-1.04)	0.89 (0.75-1.04)	0.89 (0.75-1.05)	0.89 (0.75-1.05)	0.86 (0.70-1.05)

Basic model: Individual education + area-based education + age + follow-up interval + interaction age x follow-up interval; Statistically significant estimates are printed in bold.

Table 38 Relative excess risk of death (95% posterior interval) between education groups (either individual or area-based education, basic and Q1 as reference) for colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016.

	Relative Excess Risk (95% posterior interval)				
		Adjusted for			
	Basic model	Region	Region + stage	Region + stage + cancer site	Region + stage + cancer site + urbanity
Individual Education					
Men					
Secondary	**0.87 (0.78-0.96)**	**0.86 (0.78-0.96)**	0.90 (0.81-1.00)	0.91 (0.81-1.01)	0.90 (0.81-1.00)
High	**0.73 (0.65-0.81)**	**0.73 (0.65-0.82)**	**0.77 (0.69-0.86)**	**0.77 (0.69-0.86)**	**0.76 (0.68-0.85)**
Women					
Secondary	**0.80 (0.72-0.90)**	**0.81 (0.72-0.90)**	**0.81 (0.73-0.91)**	**0.81 (0.73-0.91)**	**0.82 (0.73-0.91)**
High	**0.66 (0.58-0.76)**	**0.67 (0.59-0.77)**	**0.69 (0.61-0.79)**	**0.69 (0.61-0.79)**	**0.70 (0.61-0.79)**
Area-based Education					
Men					
Q2	0.97 (0.86-1.08)	0.98 (0.86-1.11)	1.02 (0.90-1.16)	1.02 (0.90-1.15)	0.98 (0.84-1.13)
Q3	0.98 (0.87-1.10)	1.02 (0.88-1.18)	1.01 (0.87-1.16)	1.00 (0.87-1.16)	0.96 (0.81-1.13)
Q4 (high)	0.98 (0.87-1.11)	0.98 (0.85-1.12)	0.99 (0.86-1.13)	0.98 (0.86-1.13)	0.93 (0.78-1.10)
Women					
Q2	**0.82 (0.72-0.92)**	**0.81 (0.70-0.93)**	**0.84 (0.72-0.97)**	**0.83 (0.72-0.96)**	**0.82 (0.69-0.98)**
Q3	**0.79 (0.70-0.90)**	**0.78 (0.65-0.93)**	**0.77 (0.64-0.92)**	**0.77 (0.64-0.92)**	**0.76 (0.62-0.93)**
Q4 (high)	**0.84 (0.74-0.95)**	**0.85 (0.72-0.99)**	0.85 (0.72-1.00)	0.86 (0.73-1.01)	0.83 (0.68-1.02)

Basic model: Education + age + follow-up interval + interaction age x follow-up interval;
Statistically significant estimates are printed in bold.

Figures 19 and 20 show municipality-specific RERs for men and women excluding (Figure 19) and including (Figure 20) adjustment for stage. In men, variation in RERs across municipalities was mostly related to variation across hospital districts, whereas in women, there was variation within hospital districts, too, when using individual education (Figure 19A). When including stage in the model, regional differences are less obvious in men but almost unchanged in women (Figure 20A). Variation across municipalities was smaller but the pattern did not change when RERs by municipality were adjusted for area-based education instead of individual education (Figure 19B and Figure 20B).

In sensitivity analyses, the recategorized area-based education (proportion of high educated residents) revealed similar results regarding both survival estimates and RERs (Tables 39, 40, and Figure 21). Models using imputed stage information showed similar results compared to main analyses. (Table 41).

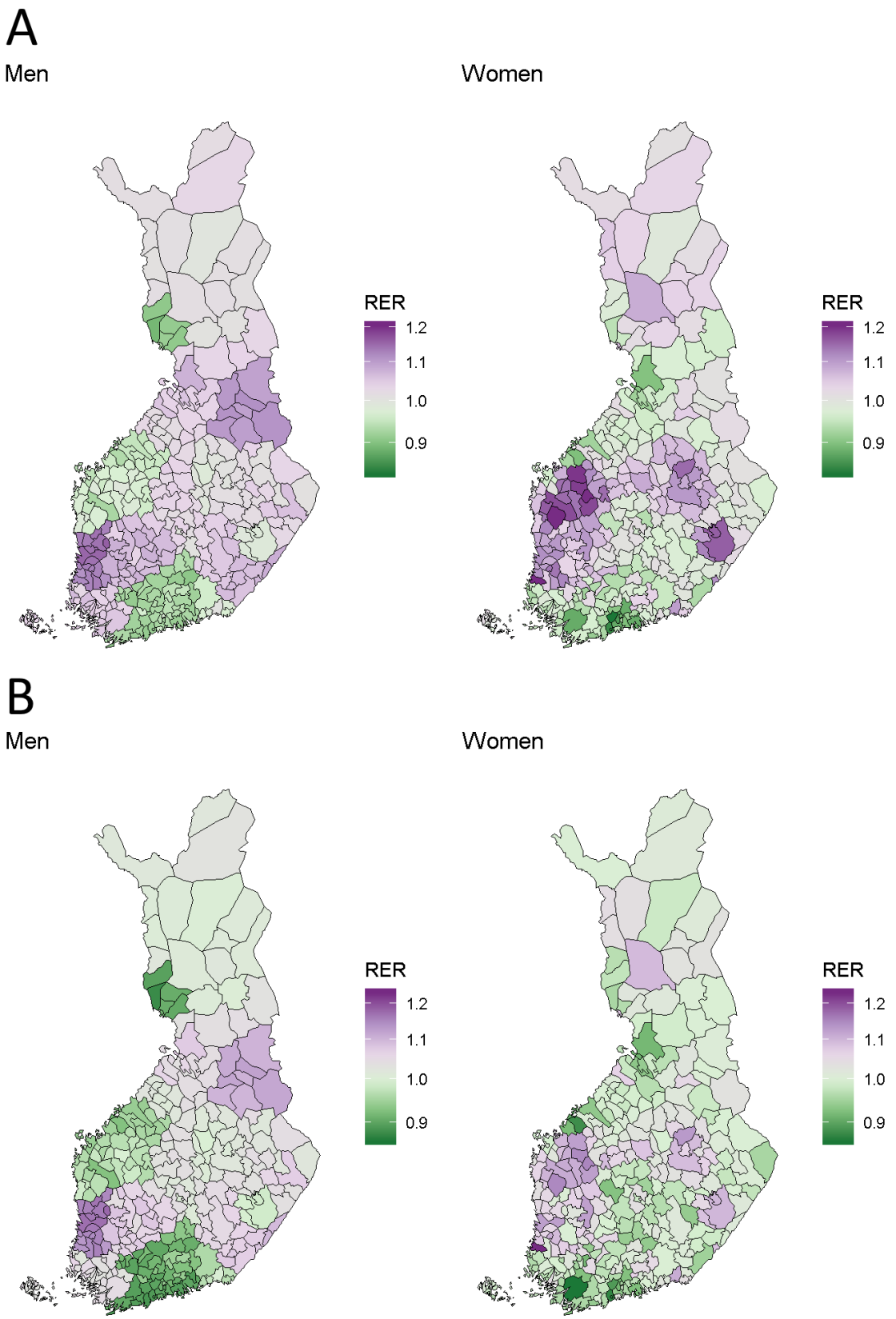

Figure 19 Relative excess risks (RER) by municipality adjusted for individual (A) or area-based (B) education and age for colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016.

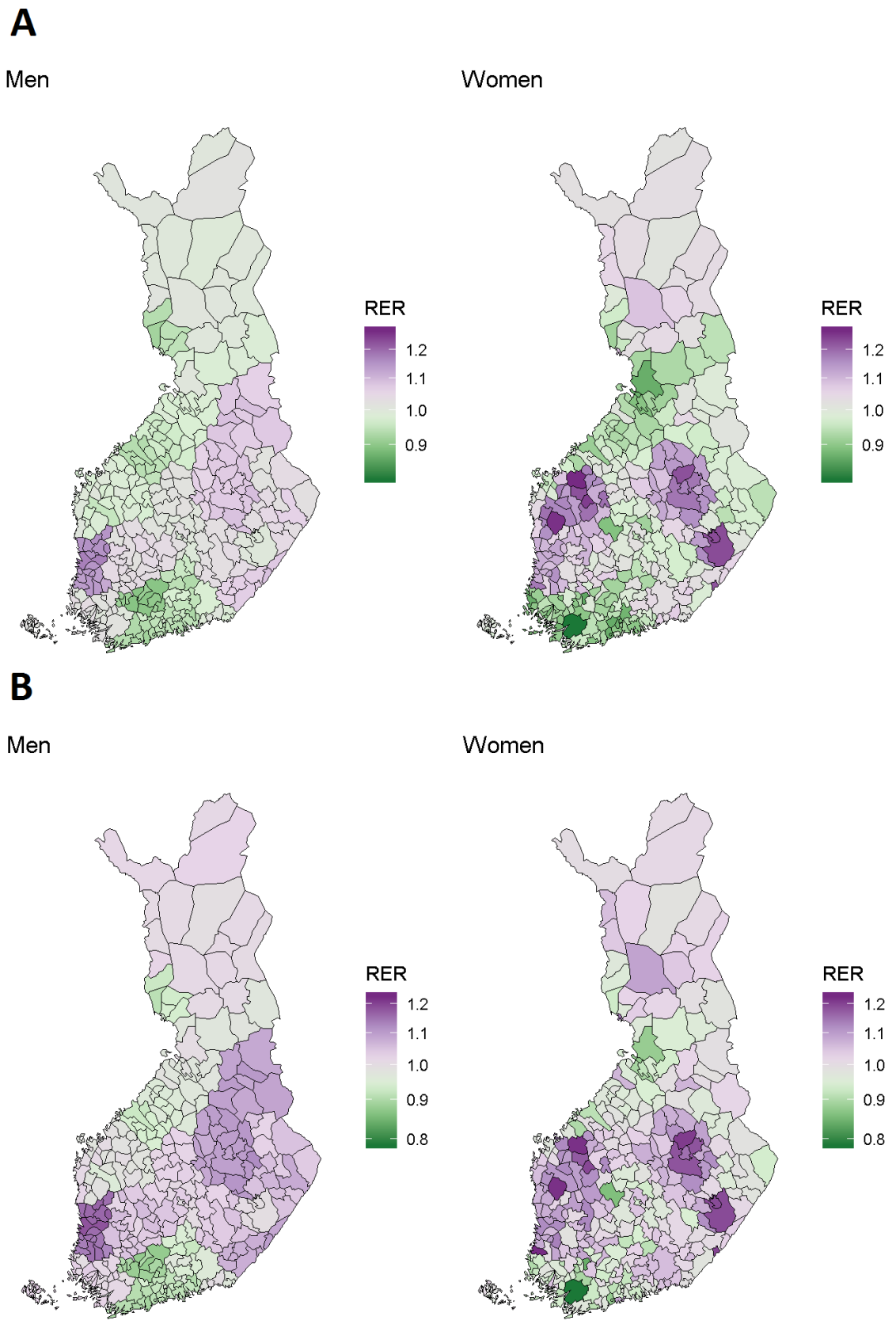

Figure 20 Relative excess risks (RER) adjusted for individual (A) or area-based (B) education, age and stage at diagnosis for colorectal cancer patients diagnosed in Finland in 2007-2016 and followed up to 2012–2016.

Table 39 Five-year age-standardized relative survival in 2012-2016 by recategorized area-based education and sex for colorectal cancer patients in Finland.

	5-year Relative Survival (95 % Confidence Interval)	
	Men	**Women**
Area-based Education*		
Colorectal		
Q1 (low)	63.5 (60.9-66.1)	61.2 (58.6-63.9)
Q2	64.4 (61.7-67.2)	65.2 (62.4-68.1)
Q3	63.3 (60.0-66.7)	67.3 (64.1-70.7)
Q4 (high)	64.1 (60.9-67.4)	67.5 (64.5-70.6)
Colon		
Q1 (low)	63.5 (60.0-67.1)	59.1 (55.9-62.5)
Q2	64.6 (60.9-68.4)	65.1 (61.7-68.6)
Q3	62.5 (58.3-67.0)	64.6 (60.7-68.8)
Q4 (high)	63.0 (58.9-67.5)	67.5 (63.8-71.3)
Rectum, rectosigmoid		
Q1 (low)	63.0 (59.2-67.0)	65.1 (60.7-69.8)
Q2	63.6 (59.6-67.8)	65.6 (61.0-70.6)
Q3	64.3 (59.2-69.8)	73.8 (68.5-79.4)
Q4 (high)	65.7 (61.0-70.8)	67.2 (62.1-72.7)

*Recategorized as proportion of high educated residents per municipality

Table 40 Relative excess risk of death (95% posterior interval) between area-based education groups (Q1 as reference) for colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016.

	Relative Excess Risk (95% posterior interval)		
		Adjusted for	
	Basic model	**Region**	**Region + stage**
Area-based Education*			
Men			
Q2	0.94 (0.84-1.05)	0.94 (0.84-1.07)	0.97 (0.86-1.10)
Q3	0.95 (0.84-1.07)	0.97 (0.84-1.12)	1.01 (0.88-1.16)
Q4 (high)	0.92 (0.82-1.04)	0.97 (0.82-1.14)	0.97 (0.83-1.14)
Women			
Q2	**0.84 (0.75-0.95)**	**0.85 (0.74-0.97)**	**0.84 (0.73-0.96)**
Q3	**0.82 (0.72-0.93)**	**0.83 (0.71-0.98)**	**0.83 (0.71-0.97)**
Q4 (high)	**0.81 (0.72-0.92)**	0.84 (0.70-1.02)	0.85 (0.70-1.04)

*Recategorized as proportion of high educated residents per municipality; Basic model: Education + age + follow-up interval + interaction age x follow-up interval; Statistically significant estimates are printed in bold.

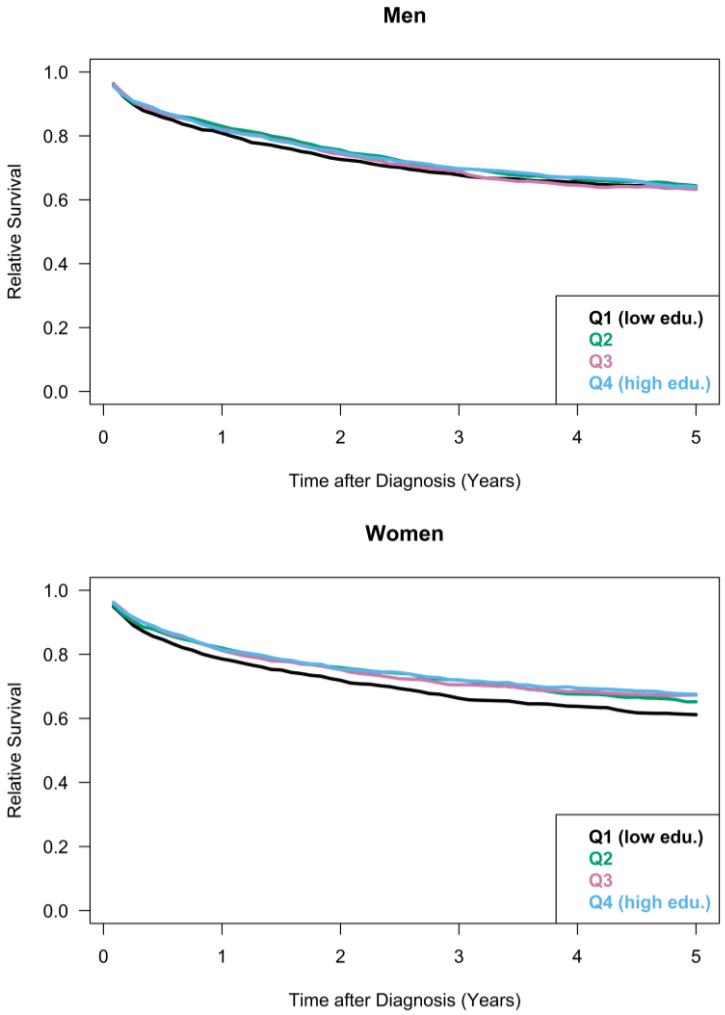

Figure 21 Age-standardized relative survival of colorectal cancer patients diagnosed in Finland in 2007-2016 and followed in 2012–2016 by recategorized area-based education (proportion of high educated residents per municipality) and sex.

Table 41 Sensitivity analysis using multiple imputation for unknown stage: Relative excess risk of death (95% confidence or posterior interval) between education groups (basic and Q1 as reference) for colorectal cancer patients diagnosed in Finland in 2007-2016.

	Relative Excess Risk (95% posterior interval) adjusted for region and stage			
	Multivariate education[1]		**Univariate education[2]**	
	Men	**Women**	**Men**	**Women**
Individual Education				
Secondary	0.90 (0.81, 1.00)	**0.82 (0.73, 0.91)**	0.91 (0.81, 1.01)	**0.81 (0.73, 0.91)**
High	**0.76 (0.68, 0.85)**	**0.70 (0.61, 0.80)**	**0.77 (0.68, 0.86)**	**0.69 (0.60, 0.78)**
Area-based education				
Q2	1.04 (0.92, 1.18)	**0.85 (0.73, 0.98)**	1.02 (0.90, 1.16)	**0.85 (0.73, 0.98)**
Q3	1.03 (0.90, 1.19)	**0.79 (0.65, 0.94)**	1.01 (0.87, 1.16)	**0.77 (0.64, 0.92)**
Q4 (high)	1.01 (0.88, 1.16)	0.87 (0.74, 1.02)	0.99 (0.86, 1.12)	**0.84 (0.72, 0.98)**

[1]Model: Individual education + area-based education + region + stage + age + follow-up interval + interaction age x follow-up interval; [2]Model: Individual or area-based education + region + stage + age + follow-up interval + interaction age x follow-up interval; Statistically significant estimates are printed in bold.

4 Discussion

4.1 Systematic review and meta-analysis[9]

This systematic review provides a comprehensive overview of the current literature on socioeconomic differences in lung cancer survival by including both individual and area-based measurements of SES. Meta-analyses for individual SES and lung cancer survival revealed a weak association for studies using income measures but no consistent association for education measures. For studies using individual income measures, no consistent difference across level of adjustment for smoking status was observed and stratified meta-analyses by stage and treatment were not possible. For individual education, results indicated that adjusting for stage and smoking status might result in smaller effect estimates. Studies using occupational measures did not report lower lung cancer survival with decreasing SES. Group comparisons for HRs of area-based studies indicated lower survival for lower SES irrespective of the socioeconomic measure. Meta-analyses for US studies reporting on area-based income showed a slightly larger estimate for the smaller geographical unit CeT compared to zip code and county level. However, comprehensiveness of adjustment was different across these studies. For the remaining area-based studies, the extent of association did not depend on the size of area-level but most studies reported an HR above 1.00 for lower-income areas. Compared to model results of individual SES studies, area-based studies in general reported stronger associations between SES and survival. Most studies reporting on survival time and survival rates revealed lower lung cancer survival in lower socioeconomic groups, not depending on individual or different area levels.

Compared to results for other cancer types, the association between individual income and survival after lung cancer diagnosis was weak. Cancers occurring in lung tissue are mostly detected in later stages (SEER 2018) which limits opportunities for cancer therapy (Cheng et al. 2016). Nevertheless, despite good treatment options for some patients, survival is still rather low (Cheng et al. 2016). Given these circumstances, the effect of SES on differences in lung cancer survival might not be as relevant as for other cancer types. The smaller effect estimates for individual education studies adjusting for stage at diagnosis supports this assumption, as this cancer type is mainly diagnosed at later stages (SEER 2018). For cancers of

[9]The different parts of this chapter are based on and were presented in the article Finke et al. 2018. The author's contribution to the different parts is declared in section 7.1.

intermediate or good prognosis, such as colorectal or breast, higher relative risks were observed (Aarts et al. 2010; Lundqvist et al. 2016).

Results of meta-analyses including individual education compared to income were rather different. This was an unexpected finding as other systematic reviews reported lower survival in low educational groups for several cancer types (Quaglia et al. 2013), such as breast (Lundqvist et al. 2016) and prostate cancer (Klein and von dem Knesebeck 2015). Furthermore, educational attainment influences occupational status which as well determines income (Quaglia et al. 2013). One explanation might be that many income studies were conducted in countries where income has a higher impact on access to and quality of health care; however, significant associations were as well reported in Scandinavian countries with universal health care systems.

Summary estimates of meta-analyses for individual and area-based income were similar, especially in studies using the smaller geographical unit US CeT. This was an unexpected finding as all area-based studies included in the meta-analyses were conducted in the USA, a country with a non-universal health care system, and individual income studies included both types of health care systems. Therefore, larger effect sizes for studies conducted in the USA were expected but due to area-based measurements of income, effects might have been diluted. The comparisons of different area-level income studies revealed a slightly higher summary estimate for the smaller US CeT unit. However, not all of these studies adjusted for stage at diagnosis. The results of the present systematic review partly confirm results of a study comparing SES measures for different geographical units in two US states in which CeT SES measures detected gradients in all-cause mortality more consistently compared to zip code level SES measures (Krieger et al. 2002). In contrast, another study examining area-based SES variables at CeT and zip code level reported small differences in effect estimates of self-rated health (Geronimus and Bound 1998). In other countries, larger effect sizes could not be observed for studies using smaller areas consistently, but studies reported rather heterogeneously. Group comparisons of area-based studies using composite measures of SES did not reveal stronger or more consistent associations depending on the size of the geographical unit, although no study reported a HR below 1.00 for those with lower SES. This result does not confirm the discussion about the importance of the use of smaller area-levels to minimize or avoid ecological fallacy (Quaglia et al. 2013; Schuurman et al. 2007). Due to the

lack of individual index studies, it was not possible to compare area-based index studies with individual studies, thus ecological bias cannot be excluded.

One study (Greenwald et al. 1994) included in the systematic review investigated directly combined effects of individual and area-based income and reported the aggregated median income on US CeT level to not add any explanatory power to the model including individual income. In this study, area-based income was not valuable as proxy measure for individual income, however, it might be reasonable to interpret area-based income as its own concept, for example regarding access to health care. The study by Greenwald and colleagues (Greenwald et al. 1994) included only a small number (N = 78) of patients diagnosed with stage II lung cancer resident in the US. To further explore differences and relationships between individual and aggregated SES measures in the context of lung cancer survival, larger studies conducted in different countries are required.

The level of adjustment for prognostic factors was very heterogeneous across studies. Most studies adjusted for age, gender, and stage and many studies additionally included variables for treatment and comorbidity. Although strongly associated with lung cancer incidence, mortality and survival (Torre et al. 2016), smoking was only considered by three individual (Aarts et al. 2013; Berglund et al. 2010; Clement-Duchene et al. 2016) and five area-based studies (Ellis et al. 2014; Kwak and Kim 2017; Ou et al. 2009; Tannenbaum et al. 2014; Yang et al. 2010). The meta-analyses stratified by adjustment for smoking suggested lower effect estimates for individual education studies adjusting for smoking status which indicates the importance of controlling for this prognostic factor. A recent analysis confirmed the contribution of smoking to socioeconomic inequalities in mortality among fourteen European countries (Gregoraci et al. 2017). Since many individual studies, especially in Scandinavia, used cancer registry data and linked these data to other registries for the SES, there might be no information on individual smoking status. Area-based studies using census data could have linked their data to area-based information on smoking status by other censuses or administrative sources. Such an approach should be considered in future studies.

Mechanisms that might lead to socioeconomic differences in lung cancer survival can include factors related to diagnosis, treatment modalities, and patients themselves (Quaglia et al. 2013). Access to health care can be both influenced by the affluence of a country or a residential area and the individual. More deprived areas can have less health care resources

which could result in a delay in diagnosis and delay in start of treatment (Quaglia et al. 2013). However, a meta-analysis on the effect of SES on stage at lung cancer diagnosis did not reveal an association (Forrest et al. 2017). The stratified meta-analysis of individual education studies in the present review did as well not show any differences which confirms the results of Forrest and colleagues (Forrest et al. 2017). For cancer therapy, socioeconomic differences have been reported regarding the administration of specific treatments as well as the referral to specialists or to oncology centers (Quaglia et al. 2013). For instance, lung and breast cancer patients belonging to deprived groups were less frequently treated by surgery in a study from England (Pollock and Vickers 1998). Due to the lack of studies stratifying by treatment in the present review this issue could not be investigated here.

4.2 Socioeconomic differences in cancer survival in Germany[10]

4.2.1 Overview analysis of data from epidemiological cancer registries

This population-based study investigated the association of area-based socioeconomic deprivation on municipality level and survival in 25 most common cancers in Germany. The results show a survival gradient from least to most deprived municipalities in the included study regions for all cancers combined. Overall, patterns were different across cancer sites. However, for most cancer sites, patients living in municipalities belonging to the most deprived quintile had significantly lower survival compared to patients from the least deprived quintile, and these differences persisted after adjusting for stage. Furthermore, the survival disadvantage of patients from the most deprived quintile was generally more pronounced in the first year after diagnosis, especially in the first three months after diagnosis, than in the longer run. Analyses by calendar periods showed increasing survival rates from earlier to more recent periods but also remaining inequalities.

The results of the present analysis are in line with findings from previous studies revealing lower cancer survival in most deprived areas (Aarts et al. 2010; Exarchakou et al. 2018; Jansen et al. 2014; Klein and von dem Knesebeck 2015; Kogevinas and Porta 1997; Lundqvist et al. 2016; Lyle et al. 2017; Manser and Bauerfeind 2014; Quaglia et al. 2013; Tron et al. 2019), even in countries with comprehensive health insurance coverage (Exarchakou et al. 2018; Lyle

[10]The different parts of this chapter are based on and were presented in two articles: Finke et al. 2020; Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

et al. 2017; Tron et al. 2019). In most countries, a gradual decrease of cancer survival with increasing area-based deprivation has been shown, in line with the present observations for several individual cancer sites and all cancers combined (Aarts et al. 2010; Exarchakou et al. 2018; Klein and von dem Knesebeck 2015; Kogevinas and Porta 1997; Lundqvist et al. 2016; Lyle et al. 2017; Manser and Bauerfeind 2014; Quaglia et al. 2013; Tron et al. 2019). The previous study by Jansen et al. (Jansen et al. 2014) using deprivation quintiles on district level (median 126,000 residents) reported no gradient across deprivation quintiles. The authors of the study discussed a higher heterogeneity within the units when using a larger area-level as possible reason for the previous findings (Jansen et al. 2014; Stanbury et al. 2016b; Woods et al. 2005). This could still be true for the absence of a survival gradient for some cancer sites in the current study despite using a much smaller area-level (median 1,194 residents). As the previous study compared the most deprived area with all other areas combined, a direct comparison of effect sizes with the present study is not possible (Jansen et al. 2014). However, the present analysis supports previous findings of stronger associations between RS and area-based socioeconomic deprivation during short term follow-up and that stage at diagnosis only partly explained the associations (Jansen et al. 2014).

Adjusting for stage at diagnosis affected derived survival estimates differently, depending on the cancer site. In prostate cancer, the association between area-based socioeconomic deprivation and lower RS was only present when not adjusting for or stratifying by stage at diagnosis. This might reflect overdiagnosis of lower stage tumors in least deprived municipalities as a result of opportunistic prostate-specific antigen screening (Spek et al. 2015). This pattern was reversed for breast cancer survival, which showed stronger associations with area-based socioeconomic deprivation after stage adjustment or stratification. Studies from the USA (Sprague et al. 2011; Yu 2009), England (McKenzie et al. 2012), and the Netherlands (Aarts et al. 2011) analyzing overall, cancer-specific or RS reported lower survival in breast cancer patients resident in more-deprived areas but attenuated associations when adjusting for stage at diagnosis. One Dutch study (Aarts et al. 2011) reported decreased effect estimates in interval and non-screen-detected breast cancer cases but slightly increased effect estimates in screening attendees after stage adjustment. In Germany, an organized mammography screening has been implemented starting in 2005 and being fully implemented in 2009 (Katalinic et al. 2020). In the age group invited for screening, late-stage breast cancer incidence and disease-specific mortality were reduced at the cost of

moderate occurrence of overdiagnosis (Katalinic et al. 2020). To explain increasing survival inequalities between area-based socioeconomic deprivation groups when adjusting for stage, more detailed analyses on breast cancer patients including information on screening attendance would be desirable.

A recent study from Germany investigated the association between area-based socioeconomic deprivation and cancer survival in colorectal patients using data from three clinical cancer registries (Jansen et al. 2020). In contrast to the present analysis, Jansen et al. (Jansen et al. 2020) reported stronger disparities in longer follow-up periods for CRC patients. However, it has to be considered that only overall survival has been calculated while the present analysis used RS (Jansen et al. 2020). Both the present and the previous study reported stronger associations in younger patients and in lower stages (Jansen et al. 2020). In general, the present results for CRC are in line with results from other countries such as the United Kingdom (Exarchakou et al. 2018; Pollock and Vickers 1997; Shack et al. 2007), the Netherlands (Schrijvers et al. 1995a), and France (Tron et al. 2019) reporting differences in 5-year RS between area-based deprivation groups.

Analyses on trends of area-based socioeconomic deprivation inequalities in RS over time showed inconsistent results across cancer sites. Although inequalities seemed to slightly decrease over time for all cancer sites combined in analyses including all cancer registries, this could not be confirmed by the sensitivity analyses restricted to cancer registries providing data for all years of diagnosis (1998-2014). In sensitivity analyses, the association for the period 2003-2005 was not as strong as in the main analyses. It is not possible to finally assess the changes from early to recent periods because first, case numbers were too low for the rather small strength of association and second, some registries could only provide data for some years of diagnosis and when only registries providing all years of diagnosis were included, the results were different. Therefore, trends of area-based socioeconomic deprivation inequalities could depend on the region in this analysis. Increasing or persistent survival disparities by area-based socioeconomic deprivation have been reported previously (Stanbury et al. 2016a) but evidence on underlying reasons and contributing factors regarding the patient, diagnosis and treatment is limited (Quaglia et al. 2013; Woods et al. 2005).

Hypothesized reasons for social inequalities in cancer survival comprise insurance status, tumor characteristics, stage, treatment, life style factors, and comorbidity (Woods et al. 2005).

As almost all German residents have access to a comprehensive health insurance program, lack of insurance is unlikely to be the reason for social inequalities. To account for variations in background mortality due to differences in life style factors and comorbidity, RS was calculated using life tables stratified by area-based socioeconomic deprivation quintiles, sex, age, and calendar year. However, it was not possible to adjust for life style factors and comorbidity beyond their impact on overall mortality. Adjusting for stage at diagnosis had only marginal effects on survival differences between area-based socioeconomic deprivation groups. It was not possible to account for differences in treatment or access to treatment. A recent study from Germany investigated the impact of treatment on CRC survival differences between area-based socioeconomic deprivation groups by using more comprehensive clinical cancer registry data, but less regions were included and overall survival was calculated (Jansen et al. 2020). CRC survival disparities between area-based socioeconomic deprivation groups persisted after adjustment for utilization of surgery as well as in subgroups receiving treatment according to guidelines (Jansen et al. 2020).

4.2.2 Analyses of data from clinical cancer registries

The analyses regarding lung and breast cancer investigated the association between small-area socioeconomic deprivation and overall (lung) or relative (breast) survival in Germany considering clinical prognostic factors and cancer therapy. Only marginal differences in patients' characteristics across municipality-level deprivation quintiles were observed. Regarding lung cancer, no clear gradient across deprivation quintiles was observed but analyses showed lowest survival in the most deprived areas. After full adjustment, a significant association between area-based socioeconomic deprivation and lung cancer survival was found for all stages combined. There was an indication for a lower overall survival for the most deprived municipalities in subgroups diagnosed in stage I-III, lower grading and with NSCLC. In contrast to lung cancer, the analysis regarding breast cancer did not show significant associations between municipality-based socioeconomic deprivation and RS. A tentative slight, but nonsignificant gradient towards lower survival in more deprived municipalities entirely disappeared when adjusting for cancer registry. By contrast, strong, statistically significant associations with poorer survival in breast cancer patients living in the catchment areas of the Erfurt und Dresden cancer registries, which include higher proportions of more deprived municipalities than the catchment area of the Regensburg cancer registry, were

observed. These differences persisted after adjustment for municipality-level socioeconomic deprivation. Taken together, these patterns suggest that larger area characteristics may be more important than municipality-level socioeconomic deprivation with respect to breast cancer survival in the included regions in Germany.

One previous study investigated associations between socioeconomic deprivation and lung and breast cancer survival in 200 of 439 districts in Germany using a broader assignment of deprivation on district rather than municipality level and computing relative survival. This study reported lower survival in lung and breast cancer patients living in the most deprived districts compared to all other districts, only adjusting for age and stage (Jansen et al. 2014). The analysis of the epidemiological cancer registries in this dissertation used municipality-level socioeconomic deprivation and confirmed the results of the previous study. However, these analyses had not controlled for district-level regional variation. The present analysis including clinical cancer registry data revealed a significant association for lung cancer overall survival but not for breast cancer relative survival after adjusting for a wider range of factors. In the analysis of breast cancer patients, the impact of deprivation on the municipality level essentially disappeared after adjusting for regional variation. The predominance of regional differences over small area socioeconomic differences observed in the present breast cancer analysis suggest that even larger-area characteristics may play a major role. The catchment areas of the Dresden, Erfurt and Regensburg registries are located in three different federal states of Germany (Saxony, Thuringia, and Bavaria), the former two being Eastern states that previously belonged to the German Democratic Republic. Despite major economic growth, socioeconomic development in the Eastern states has kept lagging behind the one in the Western states, as also reflected in the much higher proportions of municipalities in the lower GIMD quintiles in the Dresden and Erfurt registry catchment areas than in the Regensburg catchment area. A previous study showed worse 5-year RS in patients resident in Eastern Germany compared to patients resident in Western Germany for 20 out of 25 analyzed cancer sites with the largest differences for cancers of the oral cavity, oesophagus and gall bladder and skin melanoma (Jansen et al. 2012). In breast cancer patients, 5-year RS was statistically significantly lower with 82.7 % in Eastern and 83.2 % in Western Germany (0.5 %-units difference, 95 % CI: 0.1-0.9) (Jansen et al. 2012).

It is important to investigate the underlying reasons for the reported survival differences. For lung cancer, hypothesized determinants for socioeconomic inequalities in cancer survival were age, sex, year of diagnosis, stage, subtype, grading, and treatment (Berglund et al. 2010; Dalton et al. 2015). Cox models consistently revealed significantly lower survival for most deprived municipalities across all levels of adjustment unless cancer registry was added. It is therefore assumed that subtype, grading and stage might not have an impact on the association between socioeconomic deprivation and lung cancer survival in this study population. However, since the distribution of socioeconomic deprivation of municipalities was quite different across registries, the attenuation of associations by adjusting for registry catchment area or in analyses stratified by cancer registry suggests that part of the deprivation differences might be mediated by factors acting on the "supra-municipality-level". Such factors might include, for example, quality of hospital care, which would be assumed to act on a district rather than municipality level because most municipalities do not have their own hospital. In contrast to this, the analysis of breast cancer patients showed no association with deprivation but persistent survival differences between cancer registries after adjusting for the patient level factors age, stage, grading and ER. To investigate whether differences in medical care might explain the survival differences, subgroup analyses were conducted for stage I-III patients who received certain therapies. However, RS was still lower for the Dresden and Erfurt cancer registry compared to the Regensburg cancer registry in subgroups of patients receiving chemotherapy and radiotherapy. For patients diagnosed with stage I-III and ER positive breast cancer, the association of lower RS for the Dresden and Erfurt compared to the Regensburg registry even strengthened when restricting to patients who received hormone therapy. In contrast to these findings, a Swiss study reported no significant differences in breast cancer specific survival between the catchment areas of cancer registries after adjusting for age, stage, histological subtype, grading, comorbidities, and cancer therapy (Ess et al. 2018). In summary, the present results do not indicate that differences in treatment administration account for the differences in RS across the cancer registries. However, future studies with more detailed information on treatment and cancer subtype could give further insights to the causes of these regional differences in breast cancer survival. This will be possible after the full implementation of the national clinical cancer registration in Germany.

Due to data quality, it was not possible to investigate the probability of receiving a certain therapy. Recent studies on lung cancer from England reported lower odds for receiving

surgery (Belot et al. 2019; Tataru et al. 2018) but a higher probability of receiving radical radiotherapy (Tataru et al. 2018) in more deprived regions. Inequalities in treatment explained area-based socioeconomic differences in lung cancer survival for both universal and non-universal health care systems (Berglund et al. 2010; Forrest et al. 2015; Mahase et al. 2018). The present analysis revealed lower lung cancer survival for most deprived municipalities in patients receiving surgery after restricting to patients with stage I-III but effects were attenuated by further restricting to patients who received chemotherapy or radiotherapy. This might indicate survival differences by receipt of treatment. Sensitivity analyses revealed a better lung cancer survival in patients receiving chemotherapy or surgery and resident in Dresden city compared to the least deprived municipalities. As there is a comprehensive cancer center in Dresden city, access to health care might be better compared to less deprived municipalities. However, it is unclear why patients residing in Dresden city and diagnosed with high grading or SCLC have a worse survival in comparison with less deprived municipalities. In order to provide reliable evidence for all of Germany and appropriately adjust for treatment, a larger sample size and high-quality data is needed.

When comparing the present analysis of lung cancer patients to area-level index studies using similar levels of adjustment, effect estimates were larger in countries both with and without universal health care systems (e.g. The Netherlands: HR for low SES vs. high SES 1.09-1.16, (Aarts et al. 2015; Schrijvers et al. 1995a), USA: HR for low SES vs. high SES 1.05-1.38, (Gomez et al. 2016; Lara et al. 2017; Lara et al. 2014; Ou et al. 2007; Ou et al. 2008), this analysis: 1.06). Two US studies that were restricted to patients with a better prognosis (NSCLC stage I), observed overall stronger associations (HR for low SES vs. high SES 1.27-1.34) (Ou et al. 2007; Ou et al. 2008). In contrast to one US study (Gomez et al. 2016), the present analysis showed lower survival for the most deprived compared to the least deprived municipalities for men but not for women. A possible explanation might be the higher all-cause mortality (RKI 2011) and higher smoking prevalence (Zeiher and Kuntz 2017) in men compared to women in Germany. Due to missing life tables and information on smoking behavior, it was not possible to account for this in the current analysis. Adjusted 1-, 3- and 5-year survival rates were 1.7, 1.5, and 1.2 % units lower for the most compared to the least deprived regions and effect estimates were smaller than for other cancer types (Klein and von dem Knesebeck 2015; Lundqvist et al. 2016; Manser and Bauerfeind 2014). Compared to other common cancers, such as breast or colon cancer, lung cancer has a much poorer prognosis (Allemani et al. 2018),

leaving less room for the impact of socioeconomic deprivation on survival differences and resulting in smaller effect sizes for lung cancer (Quaglia et al. 2013). Supporting this hypothesis, a French study reported lower age-standardized net survival in patients resident in the most deprived areas for almost all 19 solid tumor sites with smaller differences for lung cancer patients (Tron et al. 2019). Future analyses should focus on lung cancer patients with better prognoses to further investigate social inequalities reported for these patients.

The area level on which socioeconomic differences might be relevant is subject to ongoing debate and might strongly vary between countries (Woods et al. 2005). Both municipality as well as district level analyses have advantages for investigating socioeconomic differences. On the one hand, assuming that quality of hospital care, which might be related to the socioeconomic situation in hospitals' catchment areas, might play a major role, socioeconomic deprivation on the district level may be a relevant indicator as hospitals typically serve a large number of municipalities. On the other hand, analyses on municipality level might be closer to the individual socioeconomic status of patients. That local and regional hospital care facilities might play a major role for breast cancer survival is also supported by the present findings of much better survival of breast cancer patients living in the city of Dresden, which is served to a large extent by the University Clinic of Dresden, compared to patients living in other municipalities, even though this city was classified as belonging to the third GIMD quintile only. However, this hypothesis has to be verified by further studies including factors such as regional density of hospitals and physicians or distance to a specialized breast cancer center.

Currently, there are only few other analyses in Germany regarding regional differences in cancer survival (Geiss and Meyer 2019; Nennecke et al. 2014). A study including data from 11 population-based German registries investigated differences in 5-year cancer RS between urban and rural areas (Nennecke et al. 2014). The authors reported a significantly better RS for breast cancer patients resident in city core regions compared to all other region types, with 85.4 % 5-year RS vs. around 82.0 % 5-year RS in other regions. When applying similar region types to the catchment areas of the clinical cancer registries in the present analysis, it could be categorized as follows: the region of the Dresden cancer registry is extremely urban, the Erfurt cancer registry is less urban than Dresden and the Regensburg cancer registry comprises all regions types (BBSR 2017). Combined with the results from the study by

Nennecke et al. (Nennecke et al. 2014), this categorization into region types supports the present findings of a lower RS in the Erfurt region compared to the Dresden and Regensburg region, but does not provide an explanation for the other findings of the analysis. Another study compared cancer incidence, mortality, and survival between German federal states by using funnel plots (Geiss and Meyer 2019). In general, this study did not report a difference in relative survival between the regions, however, the federal state of Bavaria was not included in survival analyses. For breast cancer patients, it could be shown that relative survival was slightly higher in Saxony compared to Thuringia, which is in line with the present findings (Geiss and Meyer 2019). To investigate regional variations in cancer survival, the level of federal states is probably too large. Further regional factors which might explain survival differences shown in the present analysis should be examined, for example regional cancer care situation.

4.3 Comparison to Finland: Education and colorectal cancer survival[11]

This analysis showed an association between lower individual educational level and lower survival of CRC patients diagnosed in 2007-2016 and followed up to 2012–2016 in Finland. This association could partly be explained by stage but not by regional variation on hospital district or municipality level. When using area-based education, educational inequalities were present only in women, although RER estimates were closer to unity. The impacts of region and stage on the association were similar to those based on individual education. In women, associations of both individual and area-based education with CRC survival were generally stronger and more consistent across models adjusting for different covariates. Results were comparable when including both individual and area-based education in the models.

In Finland, municipalities are self-governing units, have the right to levy taxes and are responsible for providing the basic services for their residents. Most of the municipalities are small (median 6,000 residents), but there are eight large municipalities with between 110,000 and 280,000 residents and the capital municipality Helsinki with a population of 630,000. The Finnish health system is highly decentralized as municipalities were obliged to organize primary care through municipal health centres since the Primary Health Care Act of 1972 (Iversen et al. 2016; Keskimaki et al. 2019). Specialist care is provided by 21 hospital districts

[11]The different parts of this chapter are based on and were presented in the article Finke, Seppä et al. 2021. The author's contribution to the different parts is declared in section 7.1.

funded by their member municipalities (Iversen et al. 2016). Each hospital district comprises one or several hospitals, including one central hospital. Five of these central hospitals are university hospitals. Residents of a given municipality needing hospital treatment are primarily treated in their own central hospital. In addition, the Ministry of Social Affairs and Health regulates the centralization of certain treatments such as demanding surgical treatments (Iversen et al. 2016). In the treatment of CRC, rectal cancer surgery was mainly centralized to the five university hospitals in 2017 (Government Decree 582/2017) (Keskimaki et al. 2019).

Irrespective of the socioeconomic measure, studies using either individual or area-based measures reported higher survival for CRC patients in higher socioeconomic groups (Aarts et al. 2010). It has been shown that measures based on large area-levels may dilute the association of social inequalities with cancer survival (Tervonen et al. 2017; Woods et al. 2005). The present study is the first to investigate this hypothesis for a comparison between individual and area-based education. The analysis demonstrated stronger associations with CRC survival differences by individual compared to area-based education. Studies investigating individual education reported higher effect estimates (HR range 1.10-2.49) (Aarts et al. 2013; Frederiksen et al. 2009; Hussain et al. 2008; Menvielle et al. 2013; Olsson and Granstrom 2014) compared to studies using area-based socioeconomic measures (HR range 1.09-1.40) (Antunes et al. 2016; Brenner et al. 1991; Dejardin et al. 2006). However, the differences in estimates might arise due to inequalities across countries and various levels of adjustment. Because area-based education only reflects the proportion of basic educated residents within a municipality, the dilution effect of area-based measures is a possible explanation for the present results. For instance, more high educated patients were categorized into Q3 than in Q4 which might induced the better survival in the Q3 group. Therefore, area-based education was not an adequate proxy measure for individual education in the analysis presented here.

Instead of considering area-based education as a substitute for individual information, it could be interpreted as a separate covariate that describes the education level in the reference population of a patient. Because differences in survival between groups of area-based education were smaller than those of individual education, it may indicate that Finnish health care system organized on area-level was able to outweigh survival inequalities between education groups. However, results for individual and area-based education were comparable

when including both measures in the models. There are two studies (Chang et al. 2012; Hagedoorn et al. 2018) combining both individual and area-based SES measures in multilevel analyses investigating CRC survival and one study (Antunes et al. 2016) comparing the single effects of both levels. A Taiwanese study using individual and neighbourhood income reported lower survival for CRC patients aged <65 years with lower income, irrespective of their residence in a high or low income neighbourhood (Chang et al. 2012). A multilevel study from Belgium showed higher mortality in women living in highly deprived neighbourhoods after controlling for individual SES (Hagedoorn et al. 2018). A Portuguese study investigating CRC survival confirmed the present results showing stronger associations with individual education compared to the area-based EDI (Antunes et al. 2016). Future studies with Finnish registry data should investigate the underlying reasons for the reported differences in area-based education in women even after adjustment for individual education.

Hypothesized determinants for educational inequalities in CRC survival were age, sex, stage, urbanity, cancer site, hospital district and municipality (Auvinen 1992; Hussain et al. 2008; Menvielle et al. 2013; Nur et al. 2015; Sjöström et al. 2018). Region and urbanity had no impact, stage had only a slight impact on the association of either individual or area-based education with CRC survival, supporting previous research (Brenner et al. 1991; Frederiksen et al. 2009; Jansen et al. 2014; Sjöström et al. 2018). In contrast to the present analysis, other studies reported either stronger associations and clearer gradients between educational groups in men (Antunes et al. 2016; Hussain et al. 2008; Menvielle et al. 2013) or similar effects between sexes (Tron et al. 2019). Factors not mediated through stage such as a patient's health condition and comorbidities but also preferences in choice of treatment could explain sex differences in the present analysis. These factors might be considered in future analyses regarding educational inequalities in CRC survival.

A direct comparison between the analysis with FCR data and the analyses with German clinical and epidemiological cancer registry data is not possible. In the analyses with German data, a socioeconomic deprivation index was used which was composed using different domains of deprivation such as education, income, municipality revenue and security (Maier 2017). The analysis with Finnish data used an individual measure of education and applied this measure to create an area-based measure of education on municipality level. Furthermore, the population structure and urbanization are different in both countries. Although the

organization of the health care system is somewhat different, both countries offer universal access to health care, therefore, similar access to cancer care can be assumed. Despite the mentioned differences, the analysis of the Finnish data was a unique chance to give an example for the difference between individual and area-based socioeconomic measures. It demonstrated the importance of using an individual measure when investigating the association between socioeconomic deprivation and cancer survival. The analyses showed stronger associations with cancer survival when using individual education instead of municipality-level education, even in models including both educational measures. In the analyses with German cancer registry data, it could not be shown that a smaller area level resulted in stronger associations with cancer survival (Jansen 2014). However, there was still the chance of ecological bias due to the heterogeneity of socioeconomic distribution in a population within a region. Additionally, the deprivation-associated differences in cancer survival in Germany cannot entirely be attributed to area-effects as it was not possible to adjust for individual SES. Currently, only one small multicentre study has been conducted to investigate individual SES and cancer survival in Germany (Singer 2017). The study population was not large enough to stratify by cancer site (Singer 2017). In the analysis of the FCR data, it was possible to link individual education to each cancer patient due to nationwide data on education. Although it might not be possible to collect nationwide data in Germany, individual SES measures should be implemented in Germany for larger regions for example federal states to further investigate survival disparities.

4.4 Strengths and Limitations

4.4.1 Systematic review and meta-analysis[12]

The systematic review including meta-analysis has important strengths and some limitations. The current literature search was conducted in four databases, which might have missed out relevant articles. The search terms were restricted to only “lung cancer” due to the large amount of search results when using the term “cancer”. This might be the reason why the number of articles found through searching reference list of included papers was high. Nevertheless, the amount of detected literature through database search was still large and it was possible to include databases specialized to the social sciences to assure inclusion of

[12]The different parts of this chapter are based on and were presented in the article Finke et al. 2018. The author’s contribution to the different parts is declared in section 7.1.

articles not only indexed in biomedical science focused databases. In addition, the quality of extracted data was enhanced by contacting authors if results were not reported clearly or incompletely to give a comprehensive view of all included studies. While the presence of a publication bias cannot completely be ruled out, which would lead to an overestimation of socioeconomic differences in cancer survival, the funnel plots for the meta-analyses did not reveal asymmetries suggesting that the probability of publication bias is rather low.

In general, studies were very heterogeneous, not only in the use of socioeconomic measures and aggregated levels but also in reporting of survival measures and in the level of adjustment. The studies have been conducted in several countries around the world including very different settings. The adjustment for key prognostic factors such as stage was often not possible. Thus, like in most epidemiologic studies, it cannot be ruled out that findings might be influenced by confounding. Furthermore, the comparison of summary estimates across subgroups (e.g. by adjustment and aggregation level) were not based on statistical tests and observed trends might be chance findings. Thus, comparison of results across studies and the conclusions derived from this review must be interpreted with caution.

The generalizability of the results to low-income countries is limited, as they were highly underrepresented and no study from Africa or South America was found. One reason for this might be the restriction to publications in English or German language in the literature search. In the present study, most individual studies were conducted in Scandinavian countries and most area-based studies were conducted in the US or United Kingdom. For other European countries as well as Asian countries, further studies are needed.

Meta-analyses stratified by gender have not been carried out. Considering papers with the largest study populations included in the review, studies reported in general a higher survival in women compared to men. However, the majority of these studies also reported similar results for women and men regarding a potential gradient according to SES. This was true for both individual and aggregated SES measurements.

Although the NOS is a tool for quality assessment of studies which is widely used, there is some critique about its validity (Stang 2010). However, the NOS gives an overview of the quality of included articles and helps to exclude studies that are not suitable to be included in a meta-analysis. Three studies were excluded from the meta-analyses because of a low quality score. These studies were also less comparable to the other studies due to other reasons: The

first study used data from clinical trials (Di Maio et al. 2012) and was therefore not representative of the underlying population, the second study only reported univariate HRs without adjustment (Herndon et al. 2008) and the third study used data of 24 institutions which could voluntarily participate in the study (Fujino 2007a). As the cut-off quality score was not set a priori, a sensitivity analysis including these three studies was conducted and revealed similar estimates. Another limitation was that there is no specific NOS coding manual for studies relying on registry data. The manual for cohort studies was used, therefore many registry studies were rated too low in the outcome section because they did not describe how mortality data were collected although it could be assumed that these data were retrieved by administrative sources with good quality (Bray and Parkin 2009). On the other hand, studies using registry data might be awarded too many points (stars) in the comparability section as their quality of measurement of potential confounders might not be as high as in usual cohort studies.

The interpretation and summary of both model and survival rate results among studies remained difficult due to diversity in SES measurements used, in particular across different countries or continents. In their review on socioeconomic differences and the risk of lung or colorectal cancer, Kuznetsov and Mielck (Kuznetsov and Mielck 2012) already found very heterogeneously reported SES measurements and therefore could not conduct a meta-analysis. However, it was still possible to perform meta-analyses in the present study by using HRs of the lowest and highest socioeconomic group which was reported by most studies. Furthermore, the focus was on model results of the studies, as most studies that reported survival rates showed age-standardized rates without any further adjustment for other prognostic factors. The restriction of using the highest and lowest SES categories for comparing the model results enabled to conduct meta-analyses with studies assessing the SES on different categories like tertiles or quintiles. The downside of this approach is that different levels of SES were compared (e.g. the lower quintile might correspond to a lower SES as compared to the lower tertile). However, as studies reported SES measures heterogeneously, this was the only way to show summarized measures for the effect of SES on lung cancer survival.

Another limitation was that it was not possible to perform stratified meta-analyses by subtypes of lung cancer because no individual study reported on SCLC patients only.

Nevertheless, meta-analyses of other important prognostic factors (stage, treatment and smoking) were conducted and revealed no major differences compared to the main analyses.

4.4.2 Overview analysis of data from epidemiological cancer registries[13]

A limitation of the present study was that it was not possible to include Germany as a whole in the analyses as no small-area level was available in federal states comprising only one city and data quality for other excluded regions was not yet sufficient for survival analyses. In total, 61 % of the German population was excluded, however, the included 39 % comprised an underlying population of about 32 million residents. The distribution of the GIMD quintiles were comparable between included and excluded areas (Jansen et al. 2014). A previous study investigating a similar study region showed that the included areas were in general representative for whole Germany regarding socioeconomic deprivation (Jansen et al. 2015). Since the previous study, data quality of German cancer registries has improved, therefore a lower cutoff value for DCO cases as inclusion criterion could be used in the present study (Jansen et al. 2014). As the proportion of DCO cases was not different across area-based socioeconomic deprivation quintiles, DCO cases should not have affected the observed gradients in survival. Another limitation was that the GIMD based on data mainly from 2006 was used and therefore changes in the distribution of area-based socioeconomic deprivation across municipalities could not be considered, especially in trend analyses. Due to data protection restrictions, it was not possible to link more than one area-based index to the cancer registry data, although the GIMD was also available for 2010. However, there were only minor changes between the GIMD 2006 and the GIMD 2010 in the distribution across municipalities. Furthermore, only the GIMD for the municipality of residence at the time of diagnosis could be considered in the present analysis. However, the time period right after diagnosis is the most critical time regarding cancer survival. Additionally, residence at time of diagnosis might represent best a patients' access to resources for cancer early detection, diagnosis and treatment. Also, the present study intended to investigate municipality-level deprivation but due to the lack of individual SES data, it could neither be concluded about the impact of individual SES on cancer survival nor the interaction of individual and area-based socioeconomic deprivation. Studies examining both measures showed that they are independently associated with cancer survival (Chang et al. 2012; Honjo et al. 2014; Wu et al.

[13]The different parts of this chapter are based on and were presented in the article Finke, Behrens et al. 2021. The author's contribution to the different parts is declared in section 7.1.

2016). Interventions to reduce social inequalities in cancer survival would mostly be implemented on area-level and not on individual-level, hence, it is reasonable to investigate area-based socioeconomic deprivation. Currently, the information on stage at diagnosis is missing for more than 35 % of the patients and the stage-groups were rather crude (localized/regional/distant). However, the completeness of stage information has strongly increased since the previous study in which missing information on stage was present for 48 % of the patients (Jansen et al. 2014). Hence, data quality of German cancer registries has improved and is going to improve through the implementation of clinical cancer registries (Arndt et al. 2019; Holleczek and Katalinic 2017).

A strength of the present analysis was the large cohort of the cancer patients of a population of 32 million German residents. Furthermore, this analysis used data from population-based cancer registries with a completeness of more than 90 % in 2014 (Arndt et al. 2019). It was possible to investigate survival differences in the 25 most common cancer sites. Area-based socioeconomic deprivation in the study region was assessed on a relatively small area-level (median population for included municipalities: 1,194 residents (Statistisches Bundesamt 2006)) which is comparable to studies from England (mean 1,500 residents (Exarchakou et al. 2018)) although the range of residents is a lot larger in the German administrative areas (IQR: 517-3,494 residents) which were not explicitly created for statistical purposes. General mortality was accounted for by computing RS using life tables stratified by sex, age, calendar year and GIMD on municipality level.

4.4.3 Analyses of data from clinical cancer registries[14]

For the lung cancer analysis, one limitation was potential residual confounding by smoking due to the lack of data on smoking behavior which is associated with SES (Avci et al. 2017). Due to missing life tables or cause of death information during the conduction of this analysis, overall survival was calculated and therefore it cannot be distinguished between cancer and other causes of death. However, as the prognosis of lung cancer patients is generally poor, survival might be similar to cause-specific or relative survival (RKI 2019). If cause-specific or relative survival instead of overall survival would have been used, the effect could be smaller compared to HRs reported in the present analysis. A reason could be differences between

[14]This chapter is based on and was presented in the article Finke et al. 2020. The author's contribution is declared in section 7.1.

deprivation groups in, for example, comorbidities (Maier et al. 2014). However, as most lung cancer patients die from lung cancer (Abdel-Rahman 2017; Janssen-Heijnen et al. 2015), this is unlikely to affect the results to a relevant degree.

For the breast cancer analysis, it was likewise not possible to include data on cause of death or comorbidities. However, it was possible to compute RS which accounts for background mortality and therefore indirectly considers comorbidities. In addition, detailed life tables stratified by age, sex, calendar year, and deprivation on municipality level were used. The national statistical office could provide data on population and deaths only after the completion of the lung cancer analysis but before the start of the breast cancer analysis. For this reason, life tables for RS could only be used in the analysis including breast cancer patients but not for lung cancer. Information on detection mode (screen-detected or non-screen-detected cases) was not available in the clinical cancer registry data. Despite a universal screening program in Germany (Katalinic et al. 2020), there might be socioeconomic deprivation differences in screening attendance between municipalities. However, the analysis showed only marginal differences in the distribution of stage at diagnosis across deprivation quintiles. Lastly, a classification into molecular subtypes was not possible due to missing data on relevant data such as progesterone receptor status and HER2 status.

The following limitations apply to both the lung and the breast cancer analysis. Although all included cancer registries verify the vital status of the patients with registration offices regularly and reported to have complete data, it cannot be excluded that the here reported survival differences originate from differences in the quality of this verification and insufficient completeness of data. Due to large proportions of missing data, no clear distinction could be made between patients not receiving a specific treatment and patients for whom such specific treatment was not recorded. However, if the treatment variable explicitly indicated that a specific therapy was actually given, this information was expected to be reliable and usable by restricting the analyses to subgroups receiving certain therapies. The use of two GIMD editions based on data from 2006 and 2010 might have affected the results regarding a change of the distribution of the GIMD across registries. From 2006 to 2010, the underlying population changed towards a slightly higher proportion in less deprived municipalities. Data from only three clinical cancer registries were included in the analyses but nationwide clinical

cancer registration is currently being implemented allowing the inclusion of more German regions in future studies.

One main strength of the analyses is the inclusion of data from three population-based clinical cancer registries with an underlying population of about 4,000,000 residents. Compared to epidemiological registries, the completeness of variables for important prognostic factors is higher in clinical cancer registries and further variables like treatment are available with improving data quality (Holleczek and Katalinic 2017; Jansen et al. 2014). Another strength is that it was possible to investigate for the first time in Germany the association between lung or breast cancer survival and socioeconomic deprivation at the municipality level (median population: 2,200 residents; IQR: 1,137-4,303 in 2010) (Statistisches Bundesamt 2019) which is comparable to countries routinely using small-area levels such as England (median population ≈ 1,500 residents) (Forrest et al. 2015). Although only including three registries, the analyzed cohort was still large and comparable to other studies investigating lung or breast cancer survival. Lastly, it was possible to include more recent periods of diagnosis from 2000-2015 for lung cancer and from 2006-2016 for breast cancer compared to the previous analysis using data from epidemiological cancer registries (Jansen et al. 2014).

4.4.4 Analysis of data from the Finnish cancer registry[15]

The analysis including data from the FCR also has some limitations. First, stage at diagnosis was only available as local or non-local and there was a rather high proportion (25 %) of unknown stage. Sensitivity analyses using multiple imputation for stage at diagnosis showed only marginal differences compared to the main analyses. The Finnish CRC screening program started in 2004 and was likely to impact regional variation in CRC survival, because only a part of the municipalities participated in the program (Malila et al. 2005). There was no information available on the patients' comorbidities in the present study. Research on the impact of comorbidities on regional or socioeconomic variations in cancer survival is still inconclusive (Frederiksen et al. 2009; Skyrud et al. 2016).

One strength of this analysis was the high quality of population-based data provided by the FCR. Compared to other registries, the FCR has a high completeness of about 96 % for all solid tumours and 97.4 % for CRC (Leinonen et al. 2017). Furthermore, due to the social security

[15]This chapter is based on and was presented in the article Finke, Seppä et al. 2021. The author's contribution is declared in section 7.1.

number which is available for each resident in Finland, it was possible to link both individual and area-based education to cancer registry data and include both measures in the models. It was possible to account appropriately for general population mortality by using RS with life tables stratified by sex, age, calendar year, individual education and hospital district. In addition to variation in survival across hospital districts, it was also possible to adjust for small area variation across municipalities. The two regional units are relevant in terms of cancer survival, because primary health care is organized by municipalities and more advanced care by hospital districts.

4.5 Conclusions[16]

The aims of this dissertation were to first give a comprehensive summary of the current literature on socioeconomic differences in lung cancer survival and then mainly to investigate deprivation-associated differences in cancer survival in Germany and if these differences depend on patient characteristics, clinical prognostic factors or cancer care. Furthermore, a comparison of survival disparities was made between individual and area-based education by using data from the FCR.

To accomplish these aims, first, a systematic review including meta-analysis was conducted. It showed that both individual income and area-based indices were associated with lower lung cancer survival but no association for individual education. These results could also be reported for Germany in this dissertation. The overall analysis including 25 cancer sites showed a lower cancer patient survival for the most deprived municipalities compared to the least deprived municipalities in Germany.

To further investigate the underlying reasons for deprivation-associated cancer survival differences, analyses including data of lung and breast cancer patients from three German clinical cancer registries were conducted. The analyses revealed different results. Regarding lung cancer, there was a lower OS in most deprived regions for the total study population even after adjusting for clinical prognostic factors. Furthermore, associations between OS and area-based deprivation for patients diagnosed in earlier stages, lower grading and with NSCLC were observed. Thus, social inequalities in cancer survival might especially be relevant for lung cancer patients with better prognoses. Regarding breast cancer, the analysis showed no statistically significant association between socioeconomic deprivation on municipality level and RS. Much more clearly shown were regional differences in RS between the three cancer registries. Recorded factors related to the tumor as well as cancer treatment did not consistently explain region-associated survival inequalities. Future research on socioeconomic differences in lung cancer survival and regional differences in breast cancer survival should focus on these patients and explore possible inequalities in the receipt of cancer treatment in detail.

[16]This chapter is based on and was presented in four articles: Finke et al. 2018; Finke et al. 2020; Finke, Seppä et al. 2021; Finke, Behrens et al.2021. The author's contribution is declared in section 7.1.

The comparison between area- and individual socioeconomic measure in the analysis of the FCR showed that municipality-level education revealed smaller effect estimates than individual education in CRC survival. Associations for individual education persisted even after adjustment for municipality-level education. These results underline the importance to investigate individual socioeconomic measures as well in Germany.

The results of this dissertation show that a further approach for Germany should be to include individual SES as well as area-based indices in analyses of cancer survival disparities. These future studies should include region, prognostic factors, complete data on cancer treatment but also other possibly relevant factors such as comorbidities. Furthermore, these analyses should be conducted stratified by cancer site as the present analyses showed different patterns for different cancer types.

5 Summary

5.1 English Summary

Area-based socioeconomic inequalities in cancer survival have been reported in several countries and for several cancer sites showing that cancer patients living in affluent regions have better survival than those living in deprived regions. It has been shown that deprivation-associated survival disparities might be more apparent when using smaller area-level deprivation measures. Possible reasons for these survival disparities could originate in differences in clinical prognostic factors or cancer care. The aims of this dissertation were to first give a comprehensive summary of the current literature on socioeconomic differences in lung cancer survival and then mainly to investigate deprivation-associated differences in cancer survival in Germany and if these differences depend on patient characteristics, clinical prognostic factors or cancer care. Furthermore, a comparison of survival disparities was made between individual and area-based education by using data for patients with colorectal cancer from the Finnish Cancer Registry.

First, a systematic review and meta-analysis was conducted including studies reporting a measure of lung cancer survival in relation to education, income, occupation, or composite measures on individual or area-based level. In total, 23 studies measured the socioeconomic status on individual level and 71 on area-based level. The meta-analyses revealed a poorer prognosis for lung cancer patients with low individual income. Group comparisons of area-based studies indicated a poorer prognosis for lower socioeconomic groups. A consistent relationship between level of aggregation and effect size could not be confirmed due to heterogeneous reporting of measurements.

To investigate the association between municipality-level socioeconomic deprivation and cancer survival in Germany, data for the 25 most common cancer sites from seven population-based cancer registries (covering 32 million inhabitants) were used. Patients were diagnosed in 1998-2014 and socioeconomic deprivation was assessed using the categorized German Index of Multiple Deprivation on municipality level. Relative survival was estimated using the period approach for 2012-2014 and model-based period analysis to calculate relative excess risk adjusted for age and stage. In total, 2,333,547 cases were included. For most cancer sites, the most deprived quintile had lower 5-year relative survival compared to the least deprived quintile even after adjusting for stage (all cancer sites combined, relative excess risk 1.16, 95 % confidence interval 1.14-1.19).

To further investigate the underlying reasons for deprivation-associated survival disparities in Germany, data from three clinical cancer registries (Regensburg, Dresden, and Erfurt, covering 4 million inhabitants) were used. Patients diagnosed with lung cancer in 2000-2015 and female patients diagnosed with breast cancer in 2006-2016 were included. For lung cancer, the association of deprivation with overall survival was investigated using Cox regression models. For breast cancer, 5-year relative survival using the period approach for 2011-2016 and model-based period analysis to calculate relative excess risk was used. Both models were adjusted for age, stage, and grading, the breast cancer models additionally for estrogen receptor status. Region-specific analyses and subgroup analyses for patients receiving specific types of treatment were conducted. Overall, 22,905 lung cancer and 31,357 breast cancer cases were included. For lung cancer, the most deprived group had a lower overall survival compared to the least deprived group in the fully adjusted model. Patients diagnosed with stage I-III showed a lower survival in the most deprived quintile which persisted when further restricting to surgery but was attenuated for chemo- or radiotherapy subgroups. For breast cancer, the fully adjusted model showed no association between deprivation and 5-year relative survival. By contrast, there was an association between region and breast cancer survival, even after adjustment for socioeconomic deprivation.

Regarding the comparison of cancer survival disparities between individual and municipality-level education, data of colorectal cancer patients diagnosed in 2007-2016 in Finland were used. Relative survival and relative excess risk were estimated by sex using period approach adjusted for age, stage at diagnosis, cancer site, urbanity, hospital district and municipality. In total, 24,462 cases were included. Area-based education revealed smaller effect estimates than individual education in colorectal cancer survival. Associations for individual education persisted even after adjustment for municipality-level education.

The results of this dissertation show that a further approach for Germany should be to include individual socioeconomic status as well as area-based indices in analyses of cancer survival disparities. These future studies should include region, prognostic factors, complete data on cancer treatment but also other possibly relevant factors such as comorbidities. Furthermore, these analyses should be conducted stratified by cancer site as the present analyses showed different patterns for different cancer types.

5.2 Deutsche Zusammenfassung

Regionsbasierte sozioökonomische Unterschiede im Krebsüberleben wurden in mehreren Ländern für unterschiedliche Krebsarten berichtet. Diese Studien zeigen, dass Krebspatienten aus wohlhabenderen Regionen ein höheres Überleben haben als Patient/-innen aus eher benachteiligten Regionen. Diese Überlebensunterschiede waren größer, je kleiner die Gebietseinheit war, anhand welcher Deprivation erhoben wurde. Unterschiede in klinischen Faktoren oder der Krebsbehandlung könnten mögliche Gründe für Überlebensunterschiede sein. Ziel dieser Dissertation war es, zunächst eine umfassende Literaturzusammenfassung zu sozioökonomischen Unterschieden im Lungenkrebsüberleben zu erstellen und dann vor allem die mit Deprivation verbundenen Unterschiede beim Krebsüberleben in Deutschland zu untersuchen und festzustellen, ob diese Unterschiede von Patienteneigenschaften, klinischen Prognosefaktoren oder der Krebsbehandlung abhängen. Darüber hinaus wurden am Beispiel von Darmkrebspatient/-innen Unterschiede im Krebsüberleben zwischen individueller und gebietsbezogener Bildung anhand von Daten des finnischen Krebsregisters untersucht.

Das systematische Review umfasste Studien, in denen Lungenkrebsüberleben bezüglich Bildung, Einkommen, Beruf oder soziökonomischer Indizes auf individueller oder gebietsbezogener Ebene berichtet wurde. Insgesamt erhoben 23 Studien den sozioökonomischen Status auf individueller und 71 auf gebietsbezogener Ebene. Metaanalysen zeigten schlechtere Prognosen für Lungenkrebspatient/-innen mit niedrigem Einkommen. Studien mit gebietsbezogener sozioökonomischer Deprivation zeigten eine schlechtere Prognose für benachteiligte Gruppen. Eine Beziehung zwischen Aggregationsgrad gebietsbezogener Deprivation und Effektgröße konnte nicht bestätigt werden.

Um den Zusammenhang zwischen sozioökonomischer Deprivation auf Gemeindeebene und Krebsüberleben in Deutschland zu untersuchen, wurden Daten der 25 häufigsten Krebsarten von 2.333.547 Fälle aus sieben bevölkerungsbezogenen Krebsregistern (32 Millionen Einwohner) für den Diagnosezeitraum 1998-2014 verwendet. Deprivation wurde anhand des „German Index of Multiple Deprivation“ auf Gemeindeebene erhoben. Relatives Überleben wurde anhand des Periodenansatzes für 2012-2014 geschätzt und „Relative Excess Risk“ (RER) wurden anhand der modellbasierten Periodenanalyse berechnet, adjustiert für Alter und Stadium. Für die meisten Krebsarten hatte die am stärksten benachteiligte Gruppe ein niedrigeres 5-Jahres Überleben im Vergleich zur am wenigsten benachteiligten Gruppe, selbst nach Stadiumsadjustierung (Krebs gesamt, RER 1,16, 95 %-Konfidenzintervall 1,14-1,19).

Um Gründe für Deprivationsabhängige Überlebensunterschiede in Deutschland weiter zu untersuchen, wurden Daten aus drei klinischen Krebsregistern (Regensburg, Dresden und Erfurt, 4 Mio. Einwohner) verwendet. Eingeschlossen wurden von 2000-2015 diagnostizierte Lungenkrebspatient/-innen, und von 2006-2016 diagnostizierte Brustkrebspatientinnen. Bei Lungenkrebs wurde der Zusammenhang zwischen Deprivation und Gesamtüberleben mithilfe von Cox-Regressionsmodellen untersucht. Für Brustkrebs wurden relatives 5-Jahres Überleben anhand des Periodenansatzes für 2011-2016 und modellbasierte Periodenanalysen zur Berechnung der RER verwendet. Die Modelle für beide Krebsarten wurden adjustiert für Alter, Stadium und Grading, die Modelle für Brustkrebs zusätzlich für Östrogenrezeptorstatus. Es wurden Regionen-spezifische Analysen und Subgruppenanalysen für Patient/-innen durchgeführt, die bestimmte Behandlungsarten erhielten. Insgesamt wurden 22.905 Lungenkrebs- und 31.357 Brustkrebsfälle untersucht. Bei Lungenkrebs wies die am stärksten benachteiligte Gruppe im voll adjustieren Modell ein geringeres Überleben auf. Patient/-innen mit Stadium I-III zeigten ein geringeres Überleben in der am stärksten benachteiligten Gruppe, auch nach Einschränkung auf die Subgruppe, die eine Operation erhalten hatte, die Assoziation in Chemo- oder Strahlentherapie Subgruppen wurde jedoch abgeschwächt. Die Brustkrebsanalyse zeigte keinen Zusammenhang zwischen Deprivation und relativem 5-Jahres Überleben. Im Gegensatz dazu bestand ein Zusammenhang zwischen Krebsregister-Region und Brustkrebsüberleben, auch nach Adjustierung für Deprivation.

Überlebensunterschiede zwischen Bildungsgruppen auf individueller und Gemeindeebene wurden mit Daten von Darmkrebspatient/-innen, diagnostiziert 2007-2016 in Finnland, analysiert. Relatives Überleben und RER wurden für 24.462 Fälle anhand des Perioden-ansatzes geschätzt, adjustiert für Alter, Stadium, Krebsart, Urbanität und Region. Gebiets-bezogene Bildung ergab niedrigere Effektschätzer als individuelle Bildung. Die Assoziation für individuelle Bildung blieb nach Adjustierung für Bildung auf Gemeindeebene bestehen.

Ein weiterer Ansatz für Deutschland sollte darin bestehen, sowohl den individuellen sozioökonomischen Status als auch gebietsbezogene Indizes in Analysen von Unterschieden im Krebsüberleben einzubeziehen. Zukünftige Studien sollten Region, prognostische Faktoren, vollständige Daten zur Krebsbehandlung, aber auch andere möglicherweise relevante Faktoren wie Komorbiditäten einbeziehen. Dies sollten krebsartspezifische Analysen sein, da vorliegende Analysen unterschiedliche Muster für verschiedene Entitäten zeigten.

6 References

Aarts, M. J., Kamphuis, C. B. M., Louwman, M. J., Coebergh, J. W. W., Mackenbach, J. P. and van Lenthe, F. J. (2013). **Educational inequalities in cancer survival: a role for comorbidities and health behaviours?** Epidemiol Community Health *67*(4), 365-373, doi: 10.1136/jech-2012-201404.

Aarts, M. J., Lemmens, V. E., Louwman, M. W., Kunst, A. E. and Coebergh, J. W. (2010). **Socioeconomic status and changing inequalities in colorectal cancer? A review of the associations with risk, treatment and outcome**. Eur J Cancer *46*(15), 2681-2695, doi: 10.1016/j.ejca.2010.04.026.

Aarts, M. J., van den Borne, B. E., Biesma, B., Kloover, J. S., Aerts, J. G. and Lemmens, V. E. (2015). **Improvement in population-based survival of stage IV NSCLC due to increased use of chemotherapy**. Int J Cancer *136*(5), e387-e395, doi: 10.1002/ijc.29216.

Aarts, M. J., Voogd, A. C., Duijm, L. E., Coebergh, J. W. and Louwman, W. J. (2011). **Socioeconomic inequalities in attending the mass screening for breast cancer in the south of the Netherlands--associations with stage at diagnosis and survival**. Breast Cancer Res Treat *128*(2), 517-525, doi: 10.1007/s10549-011-1363-z.

Abdel-Rahman, O. (2017). **Causes of death in long-term lung cancer survivors: a SEER database analysis**. Curr Med Res Opin *33*(7), 1343-1348, doi: 10.1080/03007995.2017.1322052.

Allemani, C., Matsuda, T., Di Carlo, V., Harewood, R., Matz, M., Niksic, M., Bonaventure, A., Valkov, M., Johnson, C. J., Esteve, J., Ogunbiyi, O. J., Azevedo, E. S. G., Chen, W. Q., Eser, S., Engholm, G., Stiller, C. A., Monnereau, A., Woods, R. R., Visser, O., Lim, G. H., Aitken, J., Weir, H. K. and Coleman, M. P. (2018). **Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries**. Lancet *391*(10125), 1023-1075, doi: 10.1016/s0140-6736(17)33326-3.

Allemani, C., Sant, M., Berrino, F., Aareleid, T., Chaplain, G., Coebergh, J. W., Colonna, M., Contiero, P., Danzon, A., Federico, M., Gafà, L., Grosclaude, P., Hédelin, G., Macè-Lesech, J., Garcia, C. M., Paci, E., Raverdy, N., Tretarre, B. and Williams, E. M. (2004). **Prognostic value of morphology and hormone receptor status in breast cancer - a population-based study**. Br J Cancer *91*(7), 1263-1268, doi: 10.1038/sj.bjc.6602153.

Antunes, L., Mendonca, D., Bento, M. J. and Rachet, B. (2016). **No inequalities in survival from colorectal cancer by education and socioeconomic deprivation - a population-based study in the North Region of Portugal, 2000-2002**. BMC Cancer *16*, 608, doi: 10.1186/s12885-016-2639-9.

Arndt, V., Holleczek, B., Kajüter, H., Luttmann, S., Nennecke, A., Zeissig, S. R., Kraywinkel, K. and Katalinic, A. (2019). **Data from Population-based Cancer Registration for Secondary Data Analysis: Methodological Challenges and Perspectives**. Gesundheitswesen *82*(S 01), S62-S71, doi: 10.1055/a-1009-6466.

Auvinen, A. (1992). **Social class and colon cancer survival in Finland**. Cancer *70*(2), 402-409, doi: 10.1002/1097-0142(19920715)70:2<402::aid-cncr2820700206>3.0.co;2-p.

Avci, N., Hayar, M., Altmisdortoglu, O., Tanriverdi, O., Deligonul, A., Ordu, C. and Evrensel, T. (2017). **Smoking habits are an independent prognostic factor in patients with lung cancer**. Clin Respir J *11*(5), 579-584, doi: 10.1111/crj.12386.

BBSR (2017). **Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR), Siedlungsstruktureller Regionstyp (Kreise), URL: https://www.bbsr.bund.de/BBSR/DE/forschung/raumbeobachtung/Raumabgrenzungen/deutschland/regionen/siedlungsstrukturelle-regionstypen/download-karte-regionstypen.jpg?__blob=publicationFile&v=1 [Access date: 09/04/2021]**.

Belot, A., Fowler, H., Njagi, E. N., Luque-Fernandez, M. A., Maringe, C., Magadi, W., Exarchakou, A., Quaresma, M., Turculet, A., Peake, M. D., Navani, N. and Rachet, B. (2019). **Association between age, deprivation and specific comorbid conditions and the receipt of major surgery in patients with non-small cell lung cancer in England: A population-based study**. Thorax *74*(1), 51-59, doi: 10.1136/thoraxjnl-2017-211395.

Berglund, A., Holmberg, L., Tishelman, C., Wagenius, G., Eaker, S. and Lambe, M. (2010). **Social inequalities in non-small cell lung cancer management and survival: a population-based study in central Sweden**. Thorax *65*(4), 327-333, doi: 10.1136/thx.2009.125914.

Berglund, A., Lambe, M., Luchtenborg, M., Linklater, K., Peake, M. D., Holmberg, L. and Moller, H. (2012). **Social differences in lung cancer management and survival in South East England: a cohort study**. BMJ Open *2*(3), e001048, doi: 10.1136/bmjopen-2012-001048.

Bonett, A., Roder, D. and Esterman, A. (1984). **Determinants of case survival for cancers of the lung, colon, breast and cervix in South Australia**. Med J Aust *141*(11), 705-709.

Booth, C. M., Li, G., Zhang-Salomons, J. and Mackillop, W. J. (2010). **The Impact of Socioeconomic Status on Stage of Cancer at Diagnosis and Survival A Population-Based Study in Ontario, Canada**. Cancer *116*(17), 4160-4167, doi: 10.1002/cncr.25427.

Boyd, C., Zhang-Salomons, J. Y., Groome, P. A. and Mackillop, W. J. (1999). **Associations between community income and cancer survival in Ontario, Canada, and the United States**. J Clin Oncol *17*(7), 2244-2255.

Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R. L., Torre, L. A. and Jemal, A. (2018). **Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries**. CA Cancer J Clin *68*(6), 394-424, doi: 10.3322/caac.21492.

Bray, F. and Parkin, D. M. (2009). **Evaluation of data quality in the cancer registry: principles and methods. Part I: comparability, validity and timeliness**. Eur J Cancer *45*(5), 747-755, doi: 10.1016/j.ejca.2008.11.032.

Brenner, H. and Gefeller, O. (1996). **An alternative approach to monitoring cancer patient survival**. Cancer *78*(9), 2004-2010.

Brenner, H., Gefeller, O. and Hakulinen, T. (2002). **A computer program for period analysis of cancer patient survival**. Eur J Cancer *38*(5), 690-695, doi: 10.1016/s0959-8049(02)00003-5.

Brenner, H., Gefeller, O. and Hakulinen, T. (2004). **Period analysis for 'up-to-date' cancer survival data: theory, empirical evaluation, computational realisation and applications**. Eur J Cancer *40*(3), 326-335.

Brenner, H. and Hakulinen, T. (2006). **Up-to-date and precise estimates of cancer patient survival: model-based period analysis**. Am J Epidemiol *164*(7), 689-696, doi: 10.1093/aje/kwj243.

Brenner, H., Jansen, L., Ulrich, A., Chang-Claude, J. and Hoffmeister, M. (2016a). **Survival of patients with symptom- and screening-detected colorectal cancer**. Oncotarget *7*(28), 44695-44704, doi: 10.18632/oncotarget.9412.

Brenner, H., Mielck, A., Klein, R. and Ziegler, H. (1991). **The role of socioeconomic factors in the survival of patients with colorectal cancer in Saarland/Germany**. J Clin Epidemiol *44*(8), 807-815, doi: 10.1016/0895-4356(91)90133-t.

Brenner, H., Schrotz-King, P., Holleczek, B., Katalinic, A. and Hoffmeister, M. (2016b). **Declining Bowel Cancer Incidence and Mortality in Germany**. Dtsch Arztebl Int *113*(7), 101-106, doi: 10.3238/arztebl.2016.0101.

Campbell, N. C., Elliott, A. M., Sharp, L., Ritchie, L. D., Cassidy, J. and Little, J. (2000). **Rural factors and survival from cancer: analysis of Scottish cancer registrations**. Br J Cancer *82*(11), 1863-1866, doi: 10.1054/bjoc.1999.1079.

Caposole, M. Z., Miller, K., Kim, J. N., Steward, N. A. and Bauer, T. L. (2014). **Elimination of socioeconomic and racial disparities related to lung cancer: closing the gap at a high volume community cancer center**. Surg Oncol *23*(2), 46-52, doi: 10.1016/j.suronc.2014.02.001.

Carstairs, V. and Morris, R. (1989). **Deprivation: explaining differences in mortality between Scotland and England and Wales**. Br Med J (Clin Res Ed) *299*(6704), 886-889, doi: 10.1136/bmj.299.6704.886.

Chang, C. M., Su, Y. C., Lai, N. S., Huang, K. Y., Chien, S. H., Chang, Y. H., Lian, W. C., Hsu, T. W. and Lee, C. C. (2012). **The Combined Effect of Individual and Neighborhood Socioeconomic Status on Cancer Survival Rates**. PLoS One *7*(8), e44325, doi: 10.1371/journal.pone.0044325.

Cheng, T.-Y. D., Cramb, S. M., Baade, P. D., Youlden, D. R., Nwogu, C. and Reid, M. E. (2016). **The International Epidemiology of Lung Cancer: Latest Trends, Disparities, and Tumor Characteristics**. J Thorac Oncol *11*(10), 1653-1671, doi: 10.1016/j.jtho.2016.05.021.

Cheyne, L., Taylor, A., Milton, R., Fear, J. and Callister, M. E. J. (2013). **Social deprivation does not affect lung cancer stage at presentation or disease outcome**. Lung Cancer *81*(2), 247-251, doi: 10.1016/j.lungcan.2013.03.012.

Chirikos, T. N., Reiches, N. A. and Moeschberger, M. L. (1984). **Economic differentials in cancer survival: a multivariate analysis**. J Chronic Dis *37*(3), 183-193.

Chouaid, C., Debieuvre, D., Durand-Zaleski, I., Fernandes, J., Scherpereel, A., Westeel, V., Blein, C., Gaudin, A. F., Ozan, N., Leblanc, S., Vainchtock, A., Chauvin, P., Cotte, F. E. and Souquet, P. J. (2017). **Survival inequalities in patients with lung cancer in France: A nationwide cohort study (the TERRITOIRE Study)**. PLoS One *12*(8), e0182798, doi: 10.1371/journal.pone.0182798.

Clement-Duchene, C., Stock, S., Xu, X., Chang, E. T., Gomez, S. L., West, D. W., Wakelee, H. A. and Gould, M. K. (2016). **Survival among Never-Smokers with Lung Cancer in the Cancer Care Outcomes Research and Surveillance Study**. Ann Am Thorac Soc *13*(1), 58-66, doi: 10.1513/AnnalsATS.201504-241OC.

Coleman, M. P., Babb, P., Sloggett, A., Quinn, M. and De Stavola, B. (2001). **Socioeconomic inequalities in cancer survival in England and Wales**. Cancer *91*(1), 208-216, doi: 0.1002/1097-0142(20010101)91:1+<208::aid-cncr6>3.0.co;2-e.

Coleman, M. P., Rachet, B., Woods, L. M., Mitry, E., Riga, M., Cooper, N., Quinn, M. J., Brenner, H. and Esteve, J. (2004). **Trends and socioeconomic inequalities in cancer survival in England and Wales up to 2001**. Br J Cancer *90*(7), 1367-1373, doi: 10.1038/sj.bjc.6601696.

Corazziari, I., Quinn, M. and Capocaccia, R. (2004). **Standard cancer patient population for age standardising survival ratios**. Eur J Cancer *40*(15), 2307-2316, doi: 10.1016/j.ejca.2004.07.002.

Coughlin, S. S. (2019). **Social determinants of breast cancer risk, stage, and survival**. Breast Cancer Res Treat *177*(3), 537-548, doi: 10.1007/s10549-019-05340-7.

Currow, D. C., You, H., Aranda, S., McCaughan, B. C., Morrell, S., Baker, D. F., Walton, R. and Roder, D. M. (2014). **What factors are predictive of surgical resection and survival from localised non-small cell lung cancer?** Med J Aust *201*(8), 475-480, doi: 10.5694/mja14.00365.

Dabbikeh, A., Peng, Y., Mackillop, W. J., Booth, C. M. and Zhang-Salomons, J. (2017). **Temporal trends in the association between socioeconomic status and cancer survival in Ontario: a population-based retrospective study**. CMAJ Open *5*(3), e682-e689, doi: 10.9778/cmajo.20170025.

Dalton, S. O., Olsen, M. H., Johansen, C., Olsen, J. H. and Andersen, K. K. (2019). **Socioeconomic inequality in cancer survival - changes over time. A population-based study, Denmark, 1987-2013**. Acta Oncol *58*(5), 737-744, doi: 10.1080/0284186x.2019.1566772.

Dalton, S. O., Steding-Jesen, M., Jakobsen, E., Mellemgaard, A., Osterlind, K., Schuz, J. and Johansen, C. (2015). **Socioeconomic position and survival after lung cancer: influence of stage, treatment and comorbidity among Danish patients with lung cancer diagnosed in 2004-2010**. Acta Oncol *54*(5), 797-804, doi: 10.3109/0284186x.2014.1001037.

Dalton, S. O., Steding-Jessen, M., Engholm, G., Schuz, J. and Olsen, J. H. (2008). **Social inequality and incidence of and survival from lung cancer in a population-based study in Denmark, 1994-2003**. Eur J Cancer *44*(14), 1989-1995, doi: 10.1016/j.ejca.2008.06.023.

De Angelis, R., Sant, M., Coleman, M. P., Francisci, S., Baili, P., Pierannunzio, D., Trama, A., Visser, O., Brenner, H., Ardanaz, E., Bielska-Lasota, M., Engholm, G., Nennecke, A., Siesling, S., Berrino, F. and Capocaccia, R. (2014). **Cancer survival in Europe 1999-2007 by country and age: results of EUROCARE--5-a population-based study**. Lancet Oncol *15*(1), 23-34, doi: 10.1016/s1470-2045(13)70546-1.

de Klerk, C. M., Gupta, S., Dekker, E. and Essink-Bot, M. L. (2018). **Socioeconomic and ethnic inequities within organised colorectal cancer screening programmes worldwide**. Gut *67*(4), 679-687, doi: 10.1136/gutjnl-2016-313311.

Dejardin, O., Remontet, L., Bouvier, A. M., Danzon, A., Tretarre, B., Delafosse, P., Molinie, F., Maarouf, N., Velten, M., Sauleau, E. A., Bourdon-Raverdy, N., Grosclaude, P., Boutreux, S., De Pouvourville, G. and Launoy, G. (2006). **Socioeconomic and geographic determinants of survival of patients with digestive cancer in France**. Br J Cancer *95*(7), 944-949, doi: 10.1038/sj.bjc.6603335.

Denton, E. J., Hart, D., Russell, P. A., Wright, G. and Conron, M. (2017). **Lung cancer and socio-economic status: inextricably linked to place of residence**. Intern Med J *47*(5), 563-569, doi: 10.1111/imj.13376.

DerSimonian, R. and Laird, N. (1986). **Meta-analysis in clinical trials**. Control Clin Trials *7*(3), 177-188.

Di Maio, M., Signoriello, S., Morabito, A., Rossi, A., Maione, P., Piantedosi, F., Bilancia, D., Cigolari, S., Barbera, S., Gebbia, V., Daniele, B., Robbiati, S. F., Illiano, A., Ceribelli, A., Carrozza, F., Favaretto, A., Piazza, E., Piccirillo, M. C., Daniele, G., Giordano, P., Costanzo, R., Sandomenico, C., Rocco, G., Gallo, C., Perrone, F. and Gridelli, C. (2012). **Prognostic impact of education level of patients with advanced non-small cell lung cancer enrolled in clinical trials**. Lung Cancer *76*(3), 457-464, doi: 10.1016/j.lungcan.2012.01.002.

Dickman, P. W., Sloggett, A., Hills, M. and Hakulinen, T. (2004). **Regression models for relative survival**. Stat Med *23*(1), 51-64, doi: 10.1002/sim.1597.

Eberle, A., Jansen, L., Castro, F., Krilaviciute, A., Luttmann, S., Emrich, K., Holleczek, B., Nennecke, A., Katalinic, A. and Brenner, H. (2015). **Lung cancer survival in Germany: A population-based analysis of 132,612 lung cancer patients**. Lung Cancer *90*(3), 528-533, doi: 10.1016/j.lungcan.2015.10.007.

Ederer, F. and Heise, H. (1959). **Instructions to IBM 650 programmers in processing survival computations. Bethesda (MD): National Cancer Institute**.

Ellis, L., Coleman, M. P. and Rachet, B. (2014). **The impact of life tables adjusted for smoking on the socio-economic difference in net survival for laryngeal and lung cancer**. Br J Cancer *111*(1), 195-202, doi: 10.1038/bjc.2014.217.

Erhunmwunsee, L., Joshi, M. B. M., Conlon, D. H. and Harpole, D. H. (2012). **Neighborhood-Level Socioeconomic Determinants Impact Outcomes in Nonsmall Cell Lung Cancer Patients in the Southeastern United States**. Cancer *118*(20), 5117-5123, doi: 10.1002/cncr.26185.

Ess, S. M., Herrmann, C., Bouchardy, C., Neyroud, I., Rapiti, E., Konzelmann, I., Bordoni, A., Ortelli, L., Rohrmann, S., Frick, H., Mousavi, M. and Thürlimann, B. (2018). **Impact of subtypes and comorbidities on breast cancer relapse and survival in population-based studies**. Breast *41*, 151-158, doi: 10.1016/j.breast.2018.07.011.

Evans, B. T. and Pritchard, C. (2000). **Cancer survival rates and GDP expenditure on health: a comparison of England and Wales and the USA, Denmark, Netherlands, Finland, France, Germany, Italy, Spain and Switzerland in the 1990s**. Public Health *114*(5), 336-339.

Exarchakou, A., Rachet, B., Belot, A., Maringe, C. and Coleman, M. P. (2018). **Impact of national cancer policies on cancer survival trends and socioeconomic inequalities in England, 1996-2013: population based study**. Br Med J (Clin Res Ed) *360*, k764, doi: 10.1136/bmj.k764.

Fairburn, J., Maier, W. and Braubach, M. (2016). **Incorporating Environmental Justice into Second Generation Indices of Multiple Deprivation: Lessons from the UK and Progress Internationally**. Int J Environ Res Public Health *13*(8), 750, doi: 10.3390/ijerph13080750.

Forrest, L. F., Adams, J., Rubin, G. and White, M. (2015). **The role of receipt and timeliness of treatment in socioeconomic inequalities in lung cancer survival: population-based, data-linkage study**. Thorax *70*(2), 138-145, doi: 10.1136/thoraxjnl-2014-205517.

Forrest, L. F., Sowden, S., Rubin, G., White, M. and Adams, J. (2017). **Socio-economic inequalities in stage at diagnosis, and in time intervals on the lung cancer pathway from first symptom to treatment: systematic review and meta-analysis**. Thorax *72*(5), 430-436, doi: 10.1136/thoraxjnl-2016-209013.

Frederiksen, B. L., Osler, M., Harling, H., Ladelund, S. and Jorgensen, T. (2009). **Do patient characteristics, disease, or treatment explain social inequality in survival from colorectal cancer?** Soc Sci Med *69*(7), 1107-1115, doi: 10.1016/j.socscimed.2009.07.040.

Fujino, Y. (2007a). **Anthropometry, Development History and Mortality in the Japan Collaborative Cohort Study for Evaluation of Cancer**. Asian Pac J Cancer Prev *8*(Supplement), 105-112.

Fujino, Y. (2007b). **Occupational factors and mortality in the Japan Collaborative Cohort Study for Evaluation of Cancer (JACC)**. Asian Pac J Cancer Prev *8* (Supplement), 97-104.

Galvin, A., Delva, F., Helmer, C., Rainfray, M., Bellera, C., Rondeau, V., Soubeyran, P., Coureau, G. and Mathoulin-Pélissier, S. (2018). **Sociodemographic, socioeconomic, and clinical determinants of survival in patients with cancer: A systematic review of the literature focused on the elderly**. J Geriatr Oncol *9*(1), 6-14, doi: 10.1016/j.jgo.2017.07.007.

Geiss, K. and Meyer, M. (2019). **Regional comparison of cancer incidence, mortality, and survival on the level of federal states in Germany using funnel plots**. Eur J Cancer Prev *28*(3), 234-242, doi: 10.1097/cej.0000000000000446.

Geronimus, A. T. and Bound, J. (1998). **Use of census-based aggregate variables to proxy for socioeconomic group: evidence from national samples**. Am J Epidemiol *148*(5), 475-486.

GESIS (2018). **GESIS Leibniz Institute for the Social Sciences. URL: www.gesis.org [Access date: 04/27/2018]**.

Geuter, G., Ewert, T., Deiters, T. and Hollederer, A. (2017). **[Optimization of Community Health Care: First Experiences of the Office for Medical Care in Districts and Municipalities of Bavaria]**. Gesundheitswesen *79*(1), 28-34, doi: 10.1055/s-0042-102343.

Gomez, S. L., Yang, J., Lin, S. W., McCusker, M., Sandler, A., Patel, M., Cheng, I., Wakelee, H. A. and Clarke, C. A. (2016). **Lung Cancer Survival Among Chinese Americans, 2000 to 2010**. J Glob Oncol *2*(1), 30-38, doi: 10.1200/jgo.2015.000539.

Gorey, K. M., Holowaty, E. J., Fehringer, G., Laukkanen, E., Moskowitz, A., Webster, D. J. and Richter, N. L. (1997). **An international comparison of cancer survival: Toronto, Ontario, and Detroit, Michigan, metropolitan areas**. Am J Public Health *87*(7), 1156-1163.

Greenwald, H. P., Polissar, N. L., Borgatta, E. F. and McCorkle, R. (1994). **Detecting survival effects of socioeconomic status: problems in the use of aggregate measures**. J Clin Epidemiol *47*(8), 903-909.

Greenwald, H. P., Polissar, N. L., Borgatta, E. F., McCorkle, R. and Goodman, G. (1998). **Social Factors, Treatment, And Survival In Early Stage Non Small Cell Lung Cancer**. Am J Public Health *88*(11), 1681-1684.

Gregoraci, G., van Lenthe, F. J., Artnik, B., Bopp, M., Deboosere, P., Kovacs, K., Looman, C. W. N., Martikainen, P., Menvielle, G., Peters, F., Wojtyniak, B., de Gelder, R. and Mackenbach, J. P. (2017). **Contribution of smoking to socioeconomic inequalities in mortality: a study of 14 European countries, 1990-2004**. Tob Control *26*(3), 260-268, doi: 10.1136/tobaccocontrol-2015-052766.

Grivaux, M., Zureik, M., Marsal, L., Asselain, B., Peureux, M., Chavaillon, J. M., Prudhomme, A., Carbonnelle, M., Goarant, E., Maury, B., Bedossa, A. and Blanchon, F. (2011). **Five-year survival for lung cancer patients managed in general hospitals**. Rev Mal Respir *28*(7), e31-e38, doi: 10.1016/j.rmr.2008.07.001.

Grundmann, N., Mielck, A., Siegel, M. and Maier, W. (2014). **Area deprivation and the prevalence of type 2 diabetes and obesity: analysis at the municipality level in Germany**. BMC Public Health *14*, 1264, doi: 10.1186/1471-2458-14-1264.

Guillaume, E., Pornet, C., Dejardin, O., Launay, L., Lillini, R., Vercelli, M., Marí-Dell'Olmo, M., Fernández Fontelo, A., Borrell, C., Ribeiro, A. I., Pina, M. F., Mayer, A., Delpierre, C., Rachet, B. and Launoy, G. (2016). **Development of a cross-cultural deprivation index in five European countries**. J Epidemiol Community Health *70*(5), 493-499, doi: 10.1136/jech-2015-205729.

Hagedoorn, P., Vandenheede, H., Vanthomme, K. and Gadeyne, S. (2018). **Socioeconomic position, population density and site-specific cancer mortality: A multilevel analysis of Belgian adults, 2001-2011**. Int J Cancer *142*(1), 23-35, doi: 10.1002/ijc.31031.

Hall, S., Holman, C. D., Sheiner, H. and Hendrie, D. (2004). **The influence of socio-economic and locational disadvantage on survival after a diagnosis of lung or breast cancer in Western Australia**. J Health Serv Res Policy *9*(Suppl 2), 10-16, doi: 10.1258/1355819042248116.

Hastert, T. A., Beresford, S. A. A., Sheppard, L. and White, E. (2015). **Disparities in cancer incidence and mortality by area-level socioeconomic status: a multilevel analysis**. J Epidemiol Community Health *69*(2), 168-176, doi: 10.1136/jech-2014-204417.

Haynes, R., Pearce, J. and Barnett, R. (2008). **Cancer survival in New Zealand: ethnic, social and geographical inequalities**. Soc Sci Med *67*(6), 928-937.

Herndon, J. E., Kornblith, A. B., Holland, J. C. and Paskett, E. D. (2008). **Patient education level as a predictor of survival in lung cancer clinical trials**. J Clin Oncol *26*(25), 4116-4123, doi: 10.1200/jco.2008.16.7460.

Hoebel, J., Kroll, L. E., Fiebig, J., Lampert, T., Katalinic, A., Barnes, B. and Kraywinkel, K. (2018). **Socioeconomic Inequalities in Total and Site-Specific Cancer Incidence in Germany: A Population-Based Registry Study**. Front Oncol *8*, 402, doi: 10.3389/fonc.2018.00402.

Hofmeister, C., Maier, W., Mielck, A., Stahl, L., Breckenkamp, J. and Razum, O. (2016). **[Regional Deprivation in Germany: Nation-wide Analysis of its Association with Mortality Using the German Index of Multiple Deprivation (GIMD)]**. Gesundheitswesen *78*(1), 42-48, doi: 10.1055/s-0034-1390421.

Holleczek, B., Arndt, V., Stegmaier, C. and Brenner, H. (2011). **Trends in breast cancer survival in Germany from 1976 to 2008--a period analysis by age and stage**. Cancer Epidemiol *35*(5), 399-406, doi: 10.1016/j.canep.2011.01.008.

Holleczek, B. and Katalinic, A. (2017). **Toward a comprehensive cancer registration in Germany**. Eur J Cancer Prev *26 Joining forces for better cancer registration in Europe*, S132-S138, doi: 10.1097/cej.0000000000000388.

Honjo, K., Iso, H., Fukuda, Y., Nishi, N., Nakaya, T., Fujino, Y., Tanabe, N., Suzuki, S., Subramanian, S. V. and Tamakoshi, A. (2014). **Influence of municipal- and individual-level socioeconomic conditions on mortality in Japan**. Int J Behav Med *21*(5), 737-749, doi: 10.1007/s12529-013-9337-7.

Hui, A. C., Vinod, S. K., Jalaludin, B. B., Yuile, P., Delaney, G. P. and Barton, M. B. (2005). **Socio-economic status and patterns of care in lung cancer**. Aust N Z J Public Health *29*(4), 372-377.

Hussain, S. K., Lenner, P., Sundquist, J. and Hemminki, K. (2008). **Influence of education level on cancer survival in Sweden**. Ann Oncol *19*(1), 156-162, doi: 10.1093/annonc/mdm413.

Ito, Y., Nakaya, T., Nakayama, T., Miyashiro, I., Ioka, A., Tsukuma, H. and Rachet, B. (2014). **Socioeconomic inequalities in cancer survival: a population-based study of adult patients diagnosed in Osaka, Japan, during the period 1993-2004**. Acta Oncol *53*(10), 1423-1433, doi: 10.3109/0284186x.2014.912350.

Iversen, T., Anell, A., Häkkinen, U., Kronborg, C. and Olafsdottir, T. (2016). **Coordination of health care in the Nordic countries**. Nordic Journal of Health Economics *4*(1), 41-55, doi: 10.5617/njhe.2846.

Iyen-Omofoman, B., Hubbard, R. B., Smith, C. J., Sparks, E., Bradley, E., Bourke, A. and Tata, L. J. (2011). **The distribution of lung cancer across sectors of society in the United Kingdom: a study using national primary care data**. BMC Public Health *11*, 857, doi: 10.1186/1471-2458-11-857.

Jack, R. H., Gulliford, M. C., Ferguson, J. and Moller, H. (2006). **Explaining inequalities in access to treatment in lung cancer**. J Eval Clin Pract *12*(5), 573-582, doi: 10.1111/j.1365-2753.2006.00644.x.

Jansen, L., Behrens, G., Finke, I., Maier, W., Gerken, M., Pritzkuleit, R., Holleczek, B., Brenner, H. , for the German Cancer Survival Working Group (2020). **Area-Based Socioeconomic Inequalities in Colorectal Cancer Survival in Germany: Investigation Based on Population-Based Clinical Cancer Registration**. Front Oncol *10*(857), doi: 10.3389/fonc.2020.00857.

Jansen, L., Castro, F. A., Gondos, A., Krilaviciute, A., Barnes, B., Eberle, A., Emrich, K., Hentschel, S., Holleczek, B., Katalinic, A. and Brenner, H. (2015). **Recent cancer survival in Germany: an analysis of common and less common cancers**. Int J Cancer *136*(11), 2649-2658, doi: 10.1002/ijc.29316.

Jansen, L., Eberle, A., Emrich, K., Gondos, A., Holleczek, B., Kajüter, H., Maier, W., Nennecke, A., Pritzkuleit, R. and Brenner, H. (2014). **Socioeconomic deprivation and cancer survival in**

Germany: an ecological analysis in 200 districts in Germany. Int J Cancer *134*(12), 2951-2960, doi: 10.1002/ijc.28624.

Jansen, L., Erb, C., Nennecke, A., Finke, I., Pritzkuleit, R., Holleczek, B. and Brenner, H. (2021a). **Socioeconomic deprivation and cancer survival in a metropolitan area: An analysis of cancer registry data from Hamburg, Germany**. The Lancet Regional Health – Europe *4*, doi: 10.1016/j.lanepe.2021.100063.

Jansen, L., Gondos, A., Eberle, A., Emrich, K., Holleczek, B., Katalinic, A. and Brenner, H. (2012). **Cancer survival in Eastern and Western Germany after the fall of the iron curtain**. Eur J Epidemiol *27*(9), 689-693, doi: 10.1007/s10654-012-9723-5.

Jansen, L., Kanbach, J., Finke, I., Arndt, V., Emrich, K., Holleczek, B., Kajüter, H., Kieschke, J., Maier, W., Pritzkuleit, R., Sirri, E., Schwettmann, L., Erb, C., Brenner, H., for the German Cancer Survival Working Group (2021b). **Estimation of the Potentially Avoidable Excess Deaths Associated with Socioeconomic Inequalities in Cancer Survival in Germany**. Cancers (Basel) *13*(2), doi: 10.3390/cancers13020357.

Janssen-Heijnen, M. L., van Erning, F. N., De Ruysscher, D. K., Coebergh, J. W. and Groen, H. J. (2015). **Variation in causes of death in patients with non-small cell lung cancer according to stage and time since diagnosis**. Ann Oncol *26*(5), 902-907, doi: 10.1093/annonc/mdv061.

Jeffreys, M., Sarfati, D., Stevanovic, V., Tobias, M., Lewis, C., Pearce, N. and Blakely, T. (2009). **Socioeconomic inequalities in cancer survival in New Zealand: the role of extent of disease at diagnosis**. Cancer Epidemiol Biomarkers Prev *18*(3), 915-921, doi: 10.1158/1055-9965.epi-08-0685.

Johnson, A. M., Hines, R. B., Johnson, J. A., 3rd and Bayakly, A. R. (2014). **Treatment and survival disparities in lung cancer: the effect of social environment and place of residence**. Lung Cancer *83*(3), 401-407, doi: 10.1016/j.lungcan.2014.01.008.

Johnson, A. M., Johnson, A., Hines, R. B. and Bayakly, R. (2016). **The Effects of Residential Segregation and Neighborhood Characteristics on Surgery and Survival in Patients with Early-Stage Non-Small Cell Lung Cancer**. Cancer Epidemiol Biomarkers Prev *25*(5), 750-758, doi: 10.1158/1055-9965.epi-15-1126.

Kaffashian, F., Godward, S., Davies, T., Solomon, L., McCann, J. and Duffy, S. W. (2003). **Socioeconomic effects on breast cancer survival: proportion attributable to stage and morphology**. Br J Cancer *89*(9), 1693-1696, doi: 10.1038/sj.bjc.6601339.

Katalinic, A., Eisemann, N., Kraywinkel, K., Noftz, M. R. and Hübner, J. (2020). **Breast cancer incidence and mortality before and after implementation of the German mammography screening program**. Int J Cancer *147*(3), 709-718, doi: 10.1002/ijc.32767.

Keskimaki, I., Tynkkynen, L. K., Reissell, E., Koivusalo, M., Syrja, V., Vuorenkoski, L., Rechel, B. and Karanikolos, M. (2019). **Finland: Health System Review**. Health Syst Transit *21*(2), 1-166.

Khullar, O. V., Gillespie, T., Nickleach, D. C., Liu, Y., Higgins, K., Ramalingam, S., Lipscomb, J. and Fernandez, F. G. (2015). **Socioeconomic Risk Factors for Long-Term Mortality after Pulmonary Resection for Lung Cancer: An Analysis of More than 90,000 Patients from the National Cancer Data Base**. J Am Coll Surg *220*(2), 156-168, doi: 10.1016/j.jamcollsurg.2014.10.009.

Klein, J. and von dem Knesebeck, O. (2015). **Socioeconomic inequalities in prostate cancer survival: A review of the evidence and explanatory factors**. Soc Sci Med *142*, 9-18, doi: 10.1016/j.socscimed.2015.07.006.

Kogevinas, M. and Porta, M. (1997). **Socioeconomic differences in cancer survival: a review of the evidence**. IARC Sci Publ(138), 177-206.

Kravdal, O. (2000). **Social inequalities in cancer survival**. Popul Stud (Camb) *54*(1), 1-18, doi: 10.1080/713779066.

Krieger, N., Chen, J. T., Waterman, P. D., Soobader, M. J., Subramanian, S. V. and Carson, R. (2002). **Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: the Public Health Disparities Geocoding Project**. Am J Epidemiol *156*(5), 471-482, doi: 10.1093/aje/kwf068.

Kuznetsov, L., Maier, W., Hunger, M., Meyer, M. and Mielck, A. (2012). **Regional deprivation in Bavaria, Germany: linking a new deprivation score with registry data for lung and colorectal cancer**. Int J Public Health *57*(5), 827-835, doi: 10.1007/s00038-012-0342-4.

Kuznetsov, L. and Mielck, A. (2012). **[Regional concentration of social disadvantage and of risks for lung cancer and colon cancer: systematic review and recommendations for research]**. Gesundheitswesen *74*(6), e42-e51, doi: 10.1055/s-0031-1280760.

Kwak, M. and Kim, C. (2017). **Disparities by Age, Sex, Tumor Stage, Diagnosis Path, and Area-level Socioeconomic Status in Survival Time for Major Cancers: Results from the Busan Cancer Registry**. J Korean Med Sci *32*(12), 1974-1983, doi: 10.3346/jkms.2017.32.12.1974.

Kwak, M. K., C. (2017). **Area-level Deprivation and Mortality in Subjects with Lung Cancer: A Survival Analysis from Busan, Korea**. JKDAS *19*(3), 1131-1141.

Lara, J. D., Brunson, A., Riess, J. W., Kelly, K., Lara, P. N., Jr. and Gandara, D. R. (2017). **Clinical predictors of survival in young patients with small cell lung cancer: Results from the California Cancer Registry**. Lung Cancer *112*, 165-168, doi: 10.1016/j.lungcan.2017.08.015.

Lara, M. S., Brunson, A., Wun, T., Tomlinson, B., Qi, L. H., Cress, R., Gandara, D. R. and Kelly, K. (2014). **Predictors of survival for younger patients less than 50 years of age with non-small cell lung cancer (NSCLC): A California Cancer Registry analysis**. Lung Cancer *85*(2), 264-269, doi: 10.1016/j.1ungcan.2014.04.007.

Le, H., Ziogas, A., Lipkin, S. M. and Zell, J. A. (2008). **Effects of socioeconomic status and treatment disparities in colorectal cancer survival**. Cancer Epidemiol Biomarkers Prev *17*(8), 1950-1962, doi: 10.1158/1055-9965.epi-07-2774.

Leinonen, M. K., Miettinen, J., Heikkinen, S., Pitkäniemi, J. and Malila, N. (2017). **Quality measures of the population-based Finnish Cancer Registry indicate sound data quality for solid malignant tumours**. Eur J Cancer *77*, 31-39, doi: 10.1016/j.ejca.2017.02.017.

Li, R., Daniel, R. and Rachet, B. (2016). **How much do tumor stage and treatment explain socioeconomic inequalities in breast cancer survival? Applying causal mediation analysis to population-based data**. Eur J Epidemiol *31*(6), 603-611, doi: 10.1007/s10654-016-0155-5.

Lian, M., Perez, M., Liu, Y., Schootman, M., Frisse, A., Foldes, E. and Jeffe, D. B. (2014). **Neighborhood socioeconomic deprivation, tumor subtypes, and causes of death after non-metastatic invasive breast cancer diagnosis: a multilevel competing-risk analysis**. Breast Cancer Res Treat *147*(3), 661-670, doi: 10.1007/s10549-014-3135-z.

Lipworth, L., Abelin, T. and Connelly, R. R. (1970). **Socio-economic factors in the prognosis of cancer patients**. J Chronic Dis *23*(2), 105-115.

Louwman, W. J., Aarts, M. J., Houterman, S., van Lenthe, F. J., Coebergh, J. W. W. and Janssen-Heijnen, M. L. G. (2010). **A 50% higher prevalence of life-shortening chronic conditions among cancer patients with low socioeconomic status**. Br J Cancer *103*(11), 1742-1748, doi: 10.1038/sj.bjc.6605949.

Lundqvist, A., Andersson, E., Ahlberg, I., Nilbert, M. and Gerdtham, U. (2016). **Socioeconomic inequalities in breast cancer incidence and mortality in Europe-a systematic review and meta-analysis**. Eur J Public Health *26*(5), 804-813, doi: 10.1093/eurpub/ckw070.

Lyle, G., Hendrie, G. A. and Hendrie, D. (2017). **Understanding the effects of socioeconomic status along the breast cancer continuum in Australian women: a systematic review of evidence**. Int J Equity Health *16*(1), 182, doi: 10.1186/s12939-017-0676-x.

Lyratzopoulos, G., West, C. R. and Williams, E. M. (2003). **Socioeconomic variation in colon cancer tumour factors associated with poorer prognosis**. Br J Cancer *89*(5), 828-830, doi: 10.1038/sj.bjc.6601192.

Mackillop, W. J., ZhangSalomons, J., Groome, P. A., Paszat, L. and Holowaty, E. (1997). **Socioeconomic status and cancer survival in Ontario**. J Clin Oncol *15*(4), 1680-1689.

Mahase, S., Christos, P., Wang, X., Potters, L., Wernicke, A. G. and Parashar, B. (2018). **Survival Disparities in the Radiotherapeutic Management of Lung Cancer by Regional Poverty Level**. Cureus *10*(11), e3575, doi: 10.7759/cureus.3575.

Maier, W. (2017). **[Indices of Multiple Deprivation for the analysis of regional health disparities in Germany : Experiences from epidemiology and healthcare research]**. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz *60*(12), 1403-1412, doi: 10.1007/s00103-017-2646-2.

Maier, W., Fairburn, J. and Mielck, A. (2012). **[Regional deprivation and mortality in Bavaria. Development of a community-based index of multiple deprivation]**. Gesundheitswesen *74*(7), 416-425, doi: 10.1055/s-0031-1280846.

Maier, W., Scheidt-Nave, C., Holle, R., Kroll, L. E., Lampert, T., Du, Y., Heidemann, C. and Mielck, A. (2014). **Area level deprivation is an independent determinant of prevalent type 2 diabetes and obesity at the national level in Germany. Results from the National Telephone Health Interview Surveys 'German Health Update' GEDA 2009 and 2010**. PLoS One *9*(2), e89661, doi: 10.1371/journal.pone.0089661.

Majek, O., Gondos, A., Jansen, L., Emrich, K., Holleczek, B., Katalinic, A., Nennecke, A., Eberle, A. and Brenner, H. (2012). **Survival from colorectal cancer in Germany in the early 21st century**. Br J Cancer *106*(11), 1875-1880, doi: 10.1038/bjc.2012.189.

Majek, O., Gondos, A., Jansen, L., Emrich, K., Holleczek, B., Katalinic, A., Nennecke, A., Eberle, A. and Brenner, H. (2013). **Sex differences in colorectal cancer survival: population-based analysis of 164,996 colorectal cancer patients in Germany**. PLoS One *8*(7), e68077, doi: 10.1371/journal.pone.0068077.

Malila, N., Anttila, A. and Hakama, M. (2005). **Colorectal cancer screening in Finland: details of the national screening programme implemented in Autumn 2004**. J Med Screen *12*(1), 28-32, doi: 10.1258/0969141053279095.

Manser, C. N. and Bauerfeind, P. (2014). **Impact of socioeconomic status on incidence, mortality, and survival of colorectal cancer patients: a systematic review**. Gastrointest Endosc *80*(1), 42-60, doi: 10.1016/j.gie.2014.03.011.

McKenzie, F., Ives, A. and Jeffreys, M. (2012). **Socio-economic inequalities in survival from screen-detected breast cancer in South West England: population-based cohort study**. Eur J Public Health *22*(3), 418-422, doi: 10.1093/eurpub/ckr107.

McMillan, M. T., Ojerholm, E., Verma, V., Higgins, K. A., Singhal, S., Predina, J. D., Berman, A. T., Grover, S., Robinson, C. G. and Simone, C. B., 2nd (2017). **Radiation Treatment Time and Overall Survival in Locally Advanced Non-small Cell Lung Cancer**. Int J Radiat Oncol Biol Phys *98*(5), 1142-1152, doi: 10.1016/j.ijrobp.2017.04.004.

Melvan, J. N., Sancheti, M. S., Gillespie, T., Nickleach, D. C., Liu, Y., Higgins, K., Ramalingam, S., Lipscomb, J. and Fernandez, F. G. (2015). **Nonclinical Factors Associated with 30-Day Mortality after Lung Cancer Resection: An Analysis of 215,000 Patients Using the National Cancer Data Base**. J Am Coll Surg *221*(2), 550-563, doi: 10.1016/j.jamcollsurg.2015.03.056.

Menvielle, G., Rey, G., Jougla, E. and Luce, D. (2013). **Diverging trends in educational inequalities in cancer mortality between men and women in the 2000s in France**. BMC Public Health *13*, 823, doi: 10.1186/1471-2458-13-823.

Miki, Y., Inoue, M., Ikeda, A., Sawada, N., Nakaya, T., Shimazu, T., Iwasaki, M., Yamaji, T., Sasazuki, S., Shibuya, K. and Tsugane, S. (2014). **Neighborhood deprivation and risk of cancer incidence, mortality and survival: results from a population-based cohort study in Japan**. PLoS One *9*(9), e106729, doi: 10.1371/journal.pone.0106729.

Moher, D., Liberati, A., Tetzlaff, J. and Altman, D. G. (2010). **Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement**. Int J Surg *8*(5), 336-341, doi: 10.1016/j.ijsu.2010.02.007.

Mulla, Z. D., Seo, B., Kalamegham, R. and Nuwayhid, B. S. (2009). **Multiple imputation for missing laboratory data: an example from infectious disease epidemiology**. Ann Epidemiol *19*(12), 908-914, doi: 10.1016/j.annepidem.2009.08.002.

Nennecke, A., Geiss, K., Hentschel, S., Vettorazzi, E., Jansen, L., Eberle, A., Holleczek, B., Gondos, A. and Brenner, H. (2014). **Survival of cancer patients in urban and rural areas of Germany--a comparison**. Cancer Epidemiol *38*(3), 259-265, doi: 10.1016/j.canep.2014.02.011.

Niu, X., Pawlish, K. S. and Roche, L. M. (2010). **Cancer Survival Disparities by Race/Ethnicity and Socioeconomic Status in New Jersey**. J Health Care Poor Underserved *21*(1), 144-160.

Noble, M., Wright, G., Smith, G. and Dibben, C. (2006). **Measuring Multiple Deprivation at the Small-Area Level**. Environment and Planning A: Economy and Space *38*(1), 169-185, doi: 10.1068/a37168.

Nur, U., Lyratzopoulos, G., Rachet, B. and Coleman, M. P. (2015). **The impact of age at diagnosis on socioeconomic inequalities in adult cancer survival in England**. Cancer Epidemiol *39*(4), 641-649, doi: 10.1016/j.canep.2015.05.006.

O'Dowd, E. L., McKeever, T. M., Baldwin, D. R., Anwar, S., Powell, H. A., Gibson, J. E., Iyen-Omofoman, B. and Hubbard, R. B. (2015). **What characteristics of primary care and patients are associated with early death in patients with lung cancer in the UK?** Thorax *70*(2), 161-168, doi: 10.1136/thoraxjnl-2014-205692.

Olsson, L. I. and Granstrom, F. (2014). **Socioeconomic inequalities in relative survival of rectal cancer most obvious in stage III**. World J Surg *38*(12), 3265-3275, doi: 10.1007/s00268-014-2735-4.

Ou, S. H., Zell, J. A., Ziogas, A. and Anton-Culver, H. (2007). **Prognostic factors for survival of stage I nonsmall cell lung cancer patients : a population-based analysis of 19,702 stage I patients in the California Cancer Registry from 1989 to 2003**. Cancer *110*(7), 1532-1541, doi: 10.1002/cncr.22938.

Ou, S. H., Zell, J. A., Ziogas, A. and Anton-Culver, H. (2008). **Low socioeconomic status is a poor prognostic factor for survival in stage I nonsmall cell lung cancer and is independent of surgical treatment, race, and marital status**. Cancer *112*(9), 2011-2020, doi: 10.1002/cncr.23397.

Ou, S. H., Ziogas, A. and Zell, J. A. (2009). **Prognostic factors for survival in extensive stage small cell lung cancer (ED-SCLC): the importance of smoking history, socioeconomic and marital statuses, and ethnicity**. J Thorac Oncol *4*(1), 37-43, doi: 10.1097/JTO.0b013e31819140fb.

Pagano, E., Filippini, C., Di Cuonzo, D., Ruffini, E., Zanetti, R., Rosso, S., Bertetto, O., Merletti, F. and Ciccone, G. (2010). **Factors affecting pattern of care and survival in a population-based cohort of non-small-cell lung cancer incident cases**. Cancer Epidemiol *34*(4), 483-489, doi: 10.1016/j.canep.2010.04.002.

Pastorino, U., Berrino, F., Valente, M., Gervasio, A., Sant, M., Gatta, G., Crosignani, P. and Ravasi, G. (1990). **Incident lung cancer survival. Long-term follow-up of a population-based study in Italy**. Tumori *76*(2), 199-204.

Pierga, J. Y., Mouret, E., Laurence, V., Diéras, V., Savigioni, A., Beuzeboc, P., Dorval, T., Palangié, T., Jouve, M. and Pouillart, P. (2003). **Prognostic factors for survival after neoadjuvant chemotherapy in operable breast cancer. the role of clinical response**. Eur J Cancer *39*(8), 1089-1096, doi: 10.1016/s0959-8049(03)00069-8.

Pokhrel, A., Martikainen, P., Pukkala, E., Rautalahti, M., Seppa, K. and Hakulinen, T. (2010). **Education, survival and avoidable deaths in cancer patients in Finland**. Br J Cancer *103*(7), 1109-1114, doi: 10.1038/sj.bjc.6605861.

Pollock, A. M. and Vickers, N. (1997). **Breast, lung and colorectal cancer incidence and survival in South Thames Region, 1987-1992: the effect of social deprivation**. J Public Health Med *19*(3), 288-294, doi: 10.1093/oxfordjournals.pubmed.a024632.

Pollock, A. M. and Vickers, N. (1998). **Deprivation and emergency admissions for cancers of colorectum, lung, and breast in south east England: ecological study**. Br Med J (Clin Res Ed) *317*(7153), 245-252.

Pornet, C., Delpierre, C., Dejardin, O., Grosclaude, P., Launay, L., Guittet, L., Lang, T. and Launoy, G. (2012). **Construction of an adaptable European transnational ecological deprivation index: the French version**. J Epidemiol Community Health *66*(11), 982-989, doi: 10.1136/jech-2011-200311.

Quaglia, A., Lillini, R., Mamo, C., Ivaldi, E. and Vercelli, M. (2013). **Socio-economic inequalities: a review of methodological issues and the relationships with cancer survival**. Crit Rev Oncol Hematol *85*(3), 266-277, doi: 10.1016/j.critrevonc.2012.08.007.

R-Core-Team (2013). **R: A language and environment for statistical computing. R Foundation for Statistical Computing. URL:http://www.R-project.org/ [Access date: 03/04/2019]** (R Core Team, Vienna, Austria)03/04/2019.

Rachet, B., Ellis, L., Maringe, C., Chu, T., Nur, U., Quaresma, M., Shah, A., Walters, S., Woods, L., Forman, D. and Coleman, M. P. (2010). **Socioeconomic inequalities in cancer survival in England after the NHS cancer plan**. Br J Cancer *103*(4), 446-453, doi: 10.1038/sj.bjc.6605752.

Rachet, B., Quinn, M. J., Cooper, N. and Coleman, M. P. (2008). **Survival from cancer of the lung in England and Wales up to 2001**. Br J Cancer *99*(Suppl 1), S40-S42, doi: 10.1038/sj.bjc.6604583.

Rapiti, E., Fioretta, G., Schaffar, R., Neyroud-Caspar, I., Verkooijen, H. M., Schmidlin, F., Miralbell, R., Zanetti, R. and Bouchardy, C. (2009). **Impact of socioeconomic status on prostate cancer diagnosis, treatment, and prognosis**. Cancer *115*(23), 5556-5565, doi: 10.1002/cncr.24607.

RDC (2018a). **Bevölkerungsfortschreibung, survey years 2001-2014, own calculations.** (RDC of the Federal Statistical Office and Statistical Offices of the Länder, Germany).

RDC (2018b). **Sterbefälle, survey years 2001-2014, own calculations.** (RDC of the Federal Statistical Office and Statistical Offices of the Länder, Germany).

Riaz, S. P., Horton, M., Kang, J., Mak, V., Luchtenborg, M. and Moller, H. (2011). **Lung Cancer Incidence and Survival in England An Analysis by Socioeconomic Deprivation and Urbanization**. J Thorac Oncol *6*(12), 2005-2010, doi: 10.1097/JTO.0b013e31822b02db.

Riba, L. A., Gruner, R. A., Alapati, A. and James, T. A. (2019). **Association between socioeconomic factors and outcomes in breast cancer**. Breast J *25*(3), 488-492, doi: 10.1111/tbj.13250.

Rich, A. L., Tata, L. J., Stanley, R. A., Free, C. M., Peake, M. D., Baldwin, D. R. and Hubbard, R. B. (2011). **Lung cancer in England: Information from the National Lung Cancer Audit (LUCADA)**. Lung Cancer *72*(1), 16-22, doi: 10.1016/j.lungcan.2010.07.002.

RKI (2011). **Sterblichkeit, Todesursachen und regionale Unterschiede. Gesundheitsberichterstattung des Bundes. Heft 52** (Robert Koch-Institut (Hrsg), Berlin).

RKI (2019). **Krebs in Deutschland für 2015/2016. 12. Ausgabe** (Robert Koch-Institut (Hrsg) und die Gesellschaft der epidemiologischen Krebsregister in Deutschland e.V. (Hrsg), Berlin).

Schrijvers, C. T., Coebergh, J. W., van der Heijden, L. H. and Mackenbach, J. P. (1995a). **Socioeconomic variation in cancer survival in the southeastern Netherlands, 1980-1989**. Cancer *75*(12), 2946-2953.

Schrijvers, C. T., Mackenbach, J. P., Lutz, J. M., Quinn, M. J. and Coleman, M. P. (1995b). **Deprivation, stage at diagnosis and cancer survival**. Int J Cancer *63*(3), 324-329.

Schuurman, N., Bell, N., Dunn, J. R. and Oliver, L. (2007). **Deprivation indices, population health and geography: an evaluation of the spatial effectiveness of indices at multiple scales**. J Urban Health *84*(4), 591-603, doi: 10.1007/s11524-007-9193-3.

SEER (2018). **SEER stat fact sheets: lung and bronchus cancer. URL: https://seer.cancer.gov/statfacts/html/lungb.html [Access date: 05/11/2018]** (National Cancer Institute, USA).

Seppä, K., Rue, H., Hakulinen, T., Laara, E., Sillanpaa, M. J. and Pitkäniemi, J. (2019). **Estimating multilevel regional variation in excess mortality of cancer patients using integrated nested Laplace approximation**. Stat Med *38*(5), 778-791, doi: 10.1002/sim.8010.

Shack, L. G., Rachet, B., Brewster, D. H. and Coleman, M. P. (2007). **Socioeconomic inequalities in cancer survival in Scotland 1986-2000**. Br J Cancer *97*(7), 999-1004, doi: 10.1038/sj.bjc.6603980.

Shugarman, L. R., Sorbero, M. E. S., Tian, H., Jain, A. K. and Ashwood, J. S. (2008). **An exploration of urban and rural differences in lung cancer survival among medicare beneficiaries**. Am J Public Health *98*(7), 1280-1287, doi: 10.2105/ajph.2006.099416.

Shuster, J. J. (1991). **Median follow-up in clinical trials**. J Clin Oncol *9*(1), 191-192, doi: 10.1200/jco.1991.9.1.191.

Singer, S., Bartels, M., Briest, S., Einenkel, J., Niederwieser, D., Papsdorf, K., Stolzenburg, J. U., Kunstler, S., Taubenheim, S. and Krauss, O. (2017). **Socio-economic disparities in long-term cancer**

survival-10 year follow-up with individual patient data. Support Care Cancer *25*(5), 1391-1399, doi: 10.1007/s00520-016-3528-0.

Sjöström, O., Silander, G., Syk, I., Henriksson, R., Melin, B. and Hellquist, B. N. (2018). **Disparities in colorectal cancer between Northern and Southern Sweden - a report from the new RISK North database**. Acta Oncol *57*(12), 1622-1630, doi: 10.1080/0284186x.2018.1497300.

Skyrud, K. D., Bray, F., Eriksen, M. T., Nilssen, Y. and Moller, B. (2016). **Regional variations in cancer survival: Impact of tumour stage, socioeconomic status, comorbidity and type of treatment in Norway**. Int J Cancer *138*(9), 2190-2200, doi: 10.1002/ijc.29967.

Sloggett, A., Young, H. and Grundy, E. (2007). **The association of cancer survival with four socioeconomic indicators: a longitudinal study of the older population of England and Wales 1981-2000**. BMC Cancer *7*, 20, doi: 10.1186/1471-2407-7-20.

Smailyte, G., Jasilionis, D., Vincerzevskiene, I. and Shkolnikov, V. M. (2016). **Education, survival, and avoidable deaths in Lithuanian cancer patients, 2001-2009**. Acta Oncol *55*(7), 859-864, doi: 10.3109/0284186x.2016.1156739.

Spek, A., Szabados, B., Roosen, A. and Stief, C. (2015). **PSA zur Früherkennung des Prostatakarzinoms**. Dtsch med Wochenschr *140*(19), 1435-1437, doi: 10.1055/s-0041-102939.

Spix, C., Grosche, B., Bleher, M., Kaatsch, P., Scholz-Kreisel, P. and Blettner, M. (2017). **Background gamma radiation and childhood cancer in Germany: an ecological study**. Radiat Environ Biophys *56*(2), 127-138, doi: 10.1007/s00411-017-0689-2.

Sprague, B. L., Trentham-Dietz, A., Gangnon, R. E., Ramchandani, R., Hampton, J. M., Robert, S. A., Remington, P. L. and Newcomb, P. A. (2011). **Socioeconomic status and survival after an invasive breast cancer diagnosis**. Cancer *117*(7), 1542-1551, doi: 10.1002/cncr.25589.

Stanbury, J. F., Baade, P. D., Yu, Y. and Yu, X. Q. (2016a). **Cancer survival in New South Wales, Australia: socioeconomic disparities remain despite overall improvements**. BMC Cancer *16*, 48, doi: 10.1186/s12885-016-2065-z.

Stanbury, J. F., Baade, P. D., Yu, Y. and Yu, X. Q. (2016b). **Impact of geographic area level on measuring socioeconomic disparities in cancer survival in New South Wales, Australia: A period analysis**. Cancer Epidemiol *43*, 56-62, doi: 10.1016/j.canep.2016.06.001.

Stang, A. (2010). **Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses**. Eur J Epidemiol *25*(9), 603-605, doi: 10.1007/s10654-010-9491-z.

Statistics Finland (2019a). **Official Statistics of Finland (OSF): Deaths [e-publication]. ISSN=1798-2545. URL: http://www.stat.fi/til/kuol/index_en.html [Accessed: 24.6.2019]** (Helsinki).

Statistics Finland (2019b). **Official Statistics of Finland (OSF): Educational structure of population [e-publication]. ISSN=2242-2919. URL: http://www.stat.fi/til/vkour/yht_en.html [Accessed: 18.6.2019]** (Helsinki).

Statistics Finland (2019c). **Official Statistics of Finland (OSF): Population structure [e-publication]. ISSN=1797-5395. URL: http://www.stat.fi/til/vaerak/yht_en.html [Accessed: 24.6.2019]** (Helsinki).

Statistics Finland (2020). **Statistical grouping of municipalities. URL: https://www.stat.fi/meta/kas/til_kuntaryhmit_en.html [Accessed: 20.01.2020]** (Helsinki).

Statistisches Bundesamt (2006). **Regionaldatenbank Deutschland, Tabellen 12411-02-03-5 und 12411-02-03-4. URL: https://www.regionalstatistik.de/genesis/online/ [Access date: 20/08/2019]** (Statistische Ämter des Bundes und der Länder, Deutschland).

Statistisches Bundesamt (2019). **Regionaldatenbank Deutschland, Tabelle 12411-01-01-5. URL: https://www.regionalstatistik.de/genesis/online/ [Access date: 03/04/2019]** (Statistische Ämter des Bundes und der Länder, Deutschland).

Statistisches Bundesamt (2017). **Fachserie 12 Reihe 4. Gesundheit. Todesursachen in Deutschland. URL: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Gesundheit/Todesursachen/Publikationen/Downloads-Todesursachen/todesursachen-2120400157004.pdf?__blob=publicationFile&v=5 [Access date: 22/05/2020]** (Statistische Ämter des Bundes und der Länder, Deutschland).

Stock, C., Mons, U. and Brenner, H. (2018). **Projection of cancer incidence rates and case numbers until 2030: A probabilistic approach applied to German cancer registry data (1999-2013)**. Cancer Epidemiol *57*, 110-119, doi: 10.1016/j.canep.2018.10.011.

Storm, H. H., Kejs, A. M., Engholm, G., Tryggvadottir, L., Klint, A., Bray, F. and Hakulinen, T. (2010). **Trends in the overall survival of cancer patients diagnosed 1964-2003 in the Nordic countries followed up to the end of 2006: the importance of case-mix**. Acta Oncol *49*(5), 713-724, doi: 10.3109/0284186x.2010.484426.

Sutherland, T. J. T. and Aitken, D. (2008). **Ethnic and socioeconomic inequalities in lung cancer in a New Zealand population**. Respirology *13*(4), 590-593, doi: 10.1111/j.1440-1843.2008.01301.x.

Tannenbaum, S. L., Koru-Sengul, T., Zhao, W., Miao, F. and Byrne, M. M. (2014). **Survival Disparities in Non-Small Cell Lung Cancer by Race, Ethnicity, and Socioeconomic Status**. Cancer J *20*(4), 237-245.

Tataru, D., Spencer, K., Bates, A., Wieczorek, A., Jack, R. H., Peake, M. D., Lind, M. J. and Luchtenborg, M. (2018). **Variation in geographical treatment intensity affects survival of non-small cell lung cancer patients in England**. Cancer Epidemiol *57*, 13-23, doi: 10.1016/j.canep.2018.09.001.

Tervonen, H. E., Morrell, S., Aranda, S., Roder, D., You, H., Niyonsenga, T., Walton, R., Baker, D. and Currow, D. (2017). **The impact of geographic unit of analysis on socioeconomic inequalities in cancer survival and distant summary stage - a population-based study**. Aust N Z J Public Health *41*(2), 130-136, doi: 10.1111/1753-6405.12608.

Thomson, C. S., Hole, D. J., Twelves, C. J., Brewster, D. H. and Black, R. J. (2001). **Prognostic factors in women with breast cancer: distribution by socioeconomic status and effect on differences in survival**. J Epidemiol Community Health *55*(5), 308-315, doi: 10.1136/jech.55.5.308.

Torre, L. A., Siegel, R. L., Ward, E. M. and Jemal, A. (2016). **Global Cancer Incidence and Mortality Rates and Trends-An Update**. Cancer Epidemiol Biomarkers Prev *25*(1), 16-27, doi: 10.1158/1055-9965.epi-15-0578.

Townsend, P., Phillimore, P. and Beattie, A. (1988). **Health and deprivation: inequality and the north. Routledge, London, NewYork**, Croom Helm, London.

Tron, L., Belot, A., Fauvernier, M., Remontet, L., Bossard, N., Launay, L., Bryere, J., Monnereau, A., Dejardin, O. and Launoy, G. (2019). **Socioeconomic environment and disparities in cancer survival for 19 solid tumor sites: An analysis of the French Network of Cancer Registries (FRANCIM) data**. Int J Cancer *144*(6), 1262-1274, doi: 10.1002/ijc.31951.

Twelves, C. J., Thomson, C. S., Gould, A. and Dewar, J. A. (1998). **Variation in the survival of women with breast cancer in Scotland. The Scottish Breast Cancer Focus Group and The Scottish Cancer Therapy Network**. Br J Cancer *78*(5), 566-571, doi: 10.1038/bjc.1998.541.

Vågerö, D. and Persson, G. (1987). **Cancer survival and social class in Sweden**. J Epidemiol Community Health *41*(3), 204-209.

van Buuren, S. and Groothuis-Oudshoorn, K. (2011). **mice: Multivariate Imputation by Chained Equations in R**. Journal of Statistical Software *45*(3), 67, doi: 10.18637/jss.v045.i03.

Vercelli, M., Lillini, R., Capocaccia, R., Micheli, A., Coebergh, J. W., Quinn, M., Martinez-Garcia, C., Quaglia, A. and Eldcare Working Group (2006). **Cancer survival in the elderly: Effects of socio-economic factors and health care system features (ELDCARE project)**. Eur J Cancer *42*(2), 234-242, doi: 10.1016/j.ejca.2005.07.032.

Wang, S., Sun, T., Sun, H., Li, X., Li, J., Zheng, X., Mallampati, S., Sun, H., Zhou, X., Zhou, C., Zhang, H., Cheng, Z. and Ma, H. (2017a). **Survival improvement in patients with non-small cell lung cancer between 1983 and 2012: Analysis of the Surveillance, Epidemiology, and End Results database**. Tumour Biol *39*(5), 1-13, doi: 10.1177/1010428317691677.

Wang, S., Tang, J., Sun, T., Zheng, X., Li, J., Sun, H., Zhou, X., Zhou, C., Zhang, H., Cheng, Z., Ma, H. and Sun, H. (2017b). **Survival changes in patients with small cell lung cancer and disparities between different sexes, socioeconomic statuses and ages**. Sci Rep *7*(1), 1339, doi: 10.1038/s41598-017-01571-0.

Weber, M. (1946). **Class status and power. In: Gerth H, Mills CW, editors. From MaxWeber: essays in sociology. NewYork: Oxford University Press**.

Welch, V., Petticrew, M., Petkovic, J., Moher, D., Waters, E., White, H. and Tugwell, P. (2016). **Extending the PRISMA statement to equity-focused systematic reviews (PRISMA-E 2012): explanation and elaboration**. J Clin Epidemiol *70*, 68-89, doi: 10.1016/j.jclinepi.2015.09.001.

Wells, G., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M. and Tugwell, P. **The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. URL: www.ohri.ca/programs/clinical_epidemiology/oxford.asp [Access date: 04/27/2018].**

Wen, M. and Christakis, N. A. (2005). **Neighborhood effects on posthospitalization mortality: A population-based cohort study of the elderly in Chicago**. Health Serv Res *40*(4), 1108-1127, doi: 10.1111/j.1475-6773.2005.00398.x.

Wienecke, A. and Kraywinkel, K. (2018). **[Tobacco-associated cancers in Germany-incidence and mortality trends since 1995]**. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz *61*(11), 1399-1406, doi: 10.1007/s00103-018-2821-0.

Wolters, R., Wischhusen, J., Stuber, T., Weiss, C. R., Krockberger, M., Bartmann, C., Blettner, M., Janni, W., Kreienberg, R., Schwentner, L., Novopashenny, I., Wischnewsky, M., Wockel, A. and Diessner, J. (2015). **Guidelines are advantageous, though not essential for improved survival among breast cancer patients**. Breast Cancer Res Treat *152*(2), 357-366, doi: 10.1007/s10549-015-3484-2.

Woods, L. M., Rachet, B. and Coleman, M. P. (2005). **Choice of geographic unit influences socioeconomic inequalities in breast cancer survival**. Br J Cancer *92*(7), 1279-1282, doi: 10.1038/sj.bjc.6602506.

Woods, L. M., Rachet, B. and Coleman, M. P. (2006). **Origins of socio-economic inequalities in cancer survival: a review**. Ann Oncol *17*(1), 5-19, doi: 10.1093/annonc/mdj007.

Wu, C. C., Chang, C. M., Hsu, T. W., Lee, C. H., Chen, J. H., Huang, C. Y. and Lee, C. C. (2016). **The effect of individual and neighborhood socioeconomic status on esophageal cancer survival in working-age patients in Taiwan**. Medicine (Baltimore) *95*(27), e4140, doi: 10.1097/md.0000000000004140.

Yang, R., Cheung, M. C., Byrne, M. M., Huang, Y. J., Nguyen, D., Lally, B. E. and Koniaris, L. G. (2010). **Do Racial or Socioeconomic Disparities Exist in Lung Cancer Treatment?** Cancer *116*(10), 2437-2447, doi: 10.1002/cncr.24986.

Yang, Y., Wang, G., He, J., Ren, S., Wu, F., Zhang, J. and Wang, F. (2017). **Gender differences in colorectal cancer survival: A meta-analysis**. Int J Cancer *141*(10), 1942-1949, doi: 10.1002/ijc.30827.

Yeole, B. B. (2005). **Respiratory cancer population-based survival in Mumbai, India**. Asian Pac J Cancer Prev *6*(4), 449-454.

Yeole, B. B. and Kumar, A. V. (2004). **Population-based survival from cancers having a poor prognosis in Mumbai (Bombay), India**. Asian Pac J Cancer Prev *5*(2), 175-182.

Yim, J., Hwang, S. S., Yoo, K. Y. and Kim, C. Y. (2012). **Contribution of income-related inequality and healthcare utilisation to survival in cancers of the lung, liver, stomach and colon**. J Epidemiol Community Health *66*(1), 37-40, doi: 10.1136/jech.2009.104554.

Yu, M. D., Tatalovich, Z., Gibson, J. T. and Cronin, K. A. (2014). **Using a composite index of socioeconomic status to investigate health disparities while protecting the confidentiality of cancer registry data**. Cancer Causes Control *25*(1), 81-92, doi: 10.1007/s10552-013-0310-1.

Yu, X. Q. (2009). **Socioeconomic disparities in breast cancer survival: relation to stage at diagnosis, treatment and race**. BMC Cancer *9*, 364, doi: 10.1186/1471-2407-9-364.

Yu, X. Q., O'Connell, D. L., Gibberd, R. W. and Armstrong, B. K. (2008). **Assessing the impact of socio-economic status on cancer survival in New South Wales, Australia 1996-2001**. Cancer Causes Control *19*(10), 1383-1390, doi: 10.1007/s10552-008-9210-1.

ZB-MED (2018). **The German National Library of Medicine (ZB MED) URL: www.zbmed.de/en/ [Access date: 05/14/2018]** (Germany).

Zeiher, J. and Kuntz, B. (2017). **Rauchen bei Erwachsenen in Deutschland**. Robert Koch-Institut, Epidemiologie und Gesundheitsberichterstattung *2*(2), doi: 10.17886/rki-gbe-2017-030.

Zhang-Salomons, J., Qian, H., Holowaty, E. and Mackillop, W. J. (2006). **Associations between socioeconomic status and cancer survival: choice of SES indicator may affect results**. Ann Epidemiol *16*(7), 521-528, doi: 10.1016/j.annepidem.2005.10.002.

Zhang, X., Loberiza, F. R., Klein, J. P. and Zhang, M. J. (2007). **A SAS macro for estimation of direct adjusted survival curves based on a stratified Cox regression model**. Comput Methods Programs Biomed *88*(2), 95-101, doi: 10.1016/j.cmpb.2007.07.010.

7 Own contributions and publications

The analyses presented in this dissertation are part of the project 'Regional variations in cancer survival', funded by the German Cancer Aid (Deutsche Krebshilfe), grant number 70112090. The project aimed to give a comprehensive view on regional variations in cancer survival in Germany by investigating data from epidemiological and clinical cancer registries. First, it was planned to create detailed cancer survival maps to identify regions with significantly lower survival. Second, analyses regarding the association between regional indicators on municipality level such as socioeconomic deprivation and cancer survival were organized. Third, it was purposed to investigate, if and to what extent regional variations can be explained by differences in clinical characteristics and cancer care. This analysis was planned for breast-, colorectal- and lung cancer. I was mainly involved in the implementation, conception of the study question and methodology of the second and third aim and responsible for the gathering of data, the performance of the statistical analyses, the interpretation of the results, as well as the writing of the manuscripts.

7.1 Publications and manuscripts

The different parts of the dissertation are based on and were presented in the following papers, which have been published in peer-reviewed journals.

Articles related to this dissertation

Finke I, Behrens G, Weisser L, Brenner H, Jansen L. Socioeconomic Differences and Lung Cancer Survival-Systematic Review and Meta-Analysis. Front Oncol. 2018 Nov 27; 8,536. doi: 10.3389/fonc.2018.00536.

Finke I, Behrens G, Schwettmann L, Gerken M, Pritzkuleit R, Holleczek B, Brenner H, Jansen L; German Cancer Survival Working Group. Socioeconomic differences and lung cancer survival in Germany: Investigation based on population-based clinical cancer registration. Lung Cancer. 2020 Apr; 142,1-8. doi: 10.1016/j.lungcan.2020.01.021.

Finke I, Seppä K, Malila N, Jansen L, Brenner H, Pitkäniemi J. Educational inequalities and regional variation in colorectal cancer survival in Finland. Cancer Epidemiol. 2021 Feb; 70,101858. doi: 10.1016/j.canep.2020.101858.

Finke I, Behrens G, Maier W, Schwettmann L, Pritzkuleit R, Holleczek B, Kajüter H, Gerken M, Mattutat J, Emrich K, Jansen L, Brenner H; German Cancer Survival Working Group. Small-area analysis on socioeconomic inequalities in cancer survival for 25 cancer sites in Germany. Int J Cancer. 2021 Mar 9. doi: 10.1002/ijc.33553.

My contributions to articles 1,2 and 4 include being involved in the conception of the study questions and methodology and responsible for the gathering of data, the performance of the statistical analyses, the interpretation of the results, as well as the writing of the manuscripts.

My contributions to article 3 include being responsible for conception of the study questions and methodology, the performance of the statistical analyses, the interpretation of the results, as well as the writing of the manuscript.

For all articles, co-authors provided guidance and support regarding methods, data analyses and interpretation of the results, especially the senior authors Lina Jansen and Hermann Brenner and, for the analysis of the Finnish data, Karri Seppä and Janne Pitkäniemi.

Article 1 is based on sections 2.1, 3.1, 4.1, 4.4.1, and 4.5 of this dissertation.

Article 2 is based on sections 2.2.2, 2.3.1, 2.4.2, 3.3.1, 4.2.2, 4.4.3, and 4.5 of this dissertation.

Article 3 is based on sections 2.2.3, 2.3.2, 2.4.3, 3.4, 4.3, 4.4.4, and 4.5 of this dissertation.

Article 4 is based on sections 2.2.1, 2.3.1, 2.4.1, 3.2, 4.2.1, 4.4.2, and 4.5 of this dissertation.

Other articles

Altin SV, **Finke I**, Kautz-Freimuth S, Stock S. The evolution of health literacy assessment tools: a systematic review. BMC Public Health. 2014 Nov 24; 14,1207. doi: 10.1186/1471-2458-14-1207.

Finke I, Scholz-Kreisel P, Hennewig U, Blettner M, Spix C. Radiotherapy and subsequent thyroid cancer in German childhood cancer survivors: a nested case-control study. Radiat Oncol. 2015 Oct 31; 10,219. doi: 10.1186/s13014-015-0521-6.

Finke I, de Jongste JC, Smit HA, Wijga AH, Koppelman GH, Vonk J, Brunekreef B, Gehring U. Air pollution and airway resistance at age 8 years - the PIAMA birth cohort study. Environ Health. 2018 Jul 17;17(1),61. doi: 10.1186/s12940-018-0407-9.

Jansen L, Behrens G, **Finke I**, Maier W, Gerken M, Pritzkuleit R, Holleczek B, Brenner H; German Cancer Survival Working Group. Area-Based Socioeconomic Inequalities in Colorectal Cancer Survival in Germany: Investigation Based on Population-Based Clinical Cancer Registration. Front Oncol. 2020 May 29; 10,857. doi: 10.3389/fonc.2020.00857.

Jansen L, Kanbach J, **Finke I**, Arndt V, Emrich K, Holleczek B, Kajüter H, Kieschke J, Maier W, Pritzkuleit R, Sirri E, Schwettmann L, Erb C, Brenner H, for the German Cancer Survival Working Group. Estimation of the Potentially Avoidable Excess Deaths Associated with Socioeconomic

Inequalities in Cancer Survival in Germany. Cancers (Basel). 2021 Jan 19; 13(2),357. doi: 10.3390/cancers13020357.

Weißer L, **Finke I**, Arndt V. Kardiovaskuläre Spätfolgen der Chemotherapie bei Darmkrebspatienten. Onkologe. 2021; 27, 724–738. doi: 10.1007/s00761-021-00929-4.

Jansen L, Erb C, Nennecke A, **Finke I**, Pritzkuleit R, Holleczek B and Brenner H. Socioeconomic deprivation and cancer survival in a metropolitan area: An analysis of cancer registry data from Hamburg, Germany. Lancet Reg Health Eur. 2021 Feb 26; 4:100063. doi: 10.1016/j.lanepe.2021.100063.

7.1.1 Poster presentations

Weißer L, **Finke I** and Arndt V. Chemotherapy-induced cardiotoxicity in patients with colorectal cancer: systematic review. MASCC/ISOO Annual Meeting. Vienna/Austria. 28-30 June, 2018.

Finke I, Behrens G, Schwettmann L, Gerken M, Pritzkuleit R, Holleczek B, Brenner H, Jansen L. German Cancer Survival Working Group. Socioeconomic differences and lung cancer survival in Germany: Investigation based on population-based clinical cancer registration. Joint Annual Scientific Meeting of the Society for Social Medicine & Population Health and the International Epidemiology Association European Congress 2019. Cork/Ireland. September 4-6, 2019.

Finke I, Behrens G, Schwettmann L, Gerken M, Pritzkuleit R, Holleczek B, Brenner H, Jansen L. German Cancer Survival Working Group. Socioeconomic differences and lung cancer survival in Germany: Investigation based on population-based clinical cancer registration. 34th German Cancer Congress. Berlin. February 19-22, 2020.

Finke I, Seppä K, Malila N, Jansen L, Brenner H, Pitkäniemi J. Educational inequalities and regional variation in colorectal cancer survival in Finland. 34th German Cancer Congress. Berlin. February 19-22, 2020.

Appendix

Supplementary material of the systematic review (methods)

CODING MANUAL MODIFIED NEWCASTLE-OTTAWA QUALITY ASSESSMENT SCALE

COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability.

SELECTION

1) Representativeness of the cohort
    a. Truly representative of the average residents in the community*
       Defined catchment area/geographic boundaries, whole area (complete enumeration) or random sample/census
    b. Somewhat representative of the average residents in the community*
       Membership in health maintenance organizations
    c. Selected group of users e.g. nurses, volunteers
    d. No description of the derivation of the cohort
2) Ascertainment of exposure (Socioeconomic status or Index measure)
    a. Secure record*
       E.g. surgical records, registry data, data from national/official statistics (aggregated or individual data from census)
    b. Structured interview*
    c. Written self-report (questionnaire)
    d. No description
3) Demonstration that outcome of interest was not present at start of study
    a. Yes*
       In the case of mortality/survival studies, outcome of interest is still the presence of a disease/incident, rather than death. That is to say that a statement of no history of disease or incident earns a star.
       Cancer registries always get a "yes" because they only register incident cases.
    b. No

COMPARABITLITY

1) Comparability of cohorts on the basis of the design or analysis
   A maximum of 2 stars can be allotted in this category. Both exposed and non-exposed individuals must be matched in the design and/or confounders must be adjusted for in the analysis. Statements of no differences between groups or that differences were not statistically significant are not sufficient for establishing comparability. Note: If the relative risk (or hazard ratio, HR) for the exposure of interest is adjusted for the confounders listed, then the groups will be considered to be comparable on each variable used in the adjustment. Stratification of results e.g. by age groups or gender is also considered as adjustment.
    a. Study controls for age*
    b. Study controls for any additional factor (for example: sex/gender, smoking, stage, treatment)*

OUTCOME

1) Assessment of outcome
    a. Independent blind assessment*
       Independent or blind assessment stated in the paper, or confirmation of the outcome by reference to secure records (medical records etc.)
    b. Record linkage*
       E.g. identified through ICD codes on database records (= registry data), death certificates
    c. Self-report
    d. No description
2) Was follow-up long enough for outcomes to occur
    a. Yes (adequate follow-up period: long enough to reach study aim, for example, if study reported 3 month survival rates, follow-up has to be at least 3 months)*
    b. No
3) Adequacy of follow up of cohorts
       This item assesses the follow-up of the cohort to ensure that losses are not related to either the exposure or the outcome.
    a. Complete follow up – all subjects accounted for*
       E.g. Information was ascertained through registration of other administrative offices
    b. Subjects lost to follow up unlikely to introduce bias – small number lost -> 90% follow up, or description provided of those lost*
    c. Follow up rate < 90 % and no description of those lost
    d. No statement

Supplementary material of the systematic review (results)

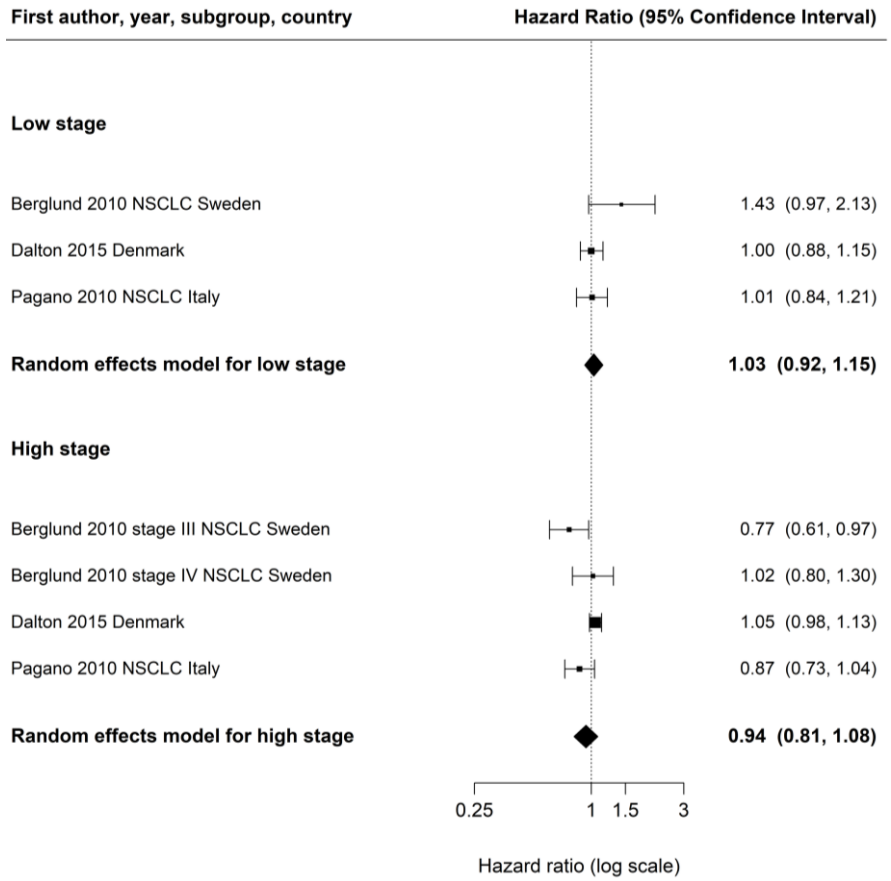

Figure A1 Meta-analyses of the association between individual education (reference: high education) and lung cancer survival stratified by stage (low stage = stage I/II (TNM version 5/6) and high stage = stage III/IV).

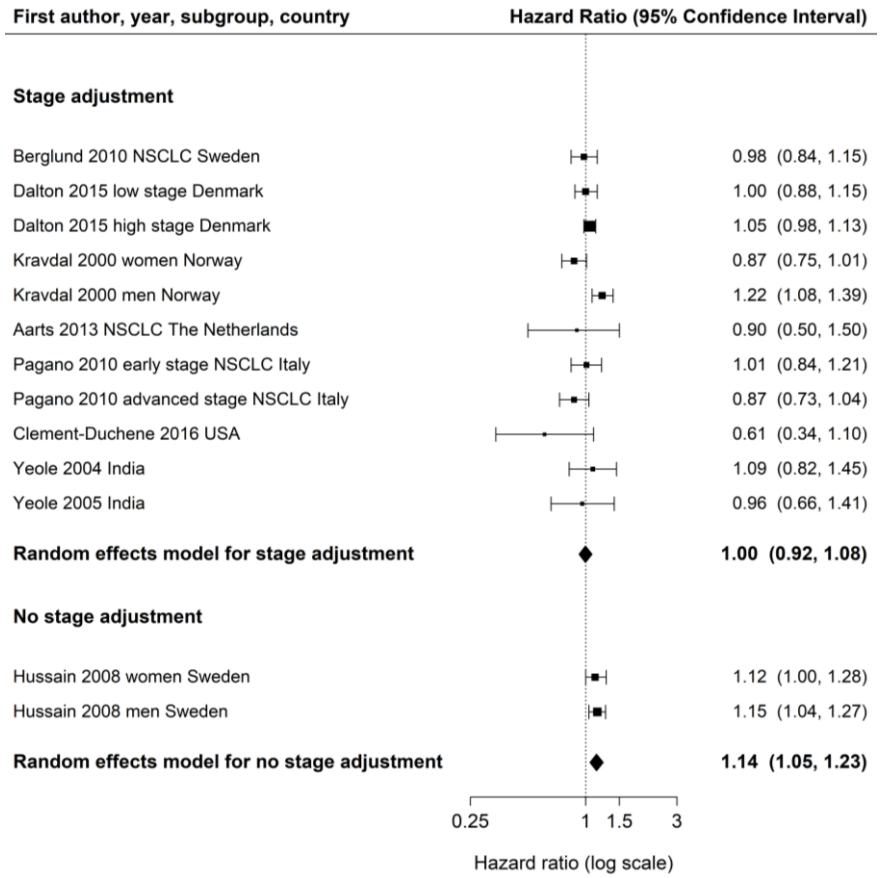

Figure A2 Meta-analysis of the association between individual education (reference: high education) and lung cancer survival stratified by stage adjustment, order by region: Europe, USA, Asia. NSCLC = non-small cell lung cancer. Clement-Duchene 2016 included non-smokers only in their analysis.

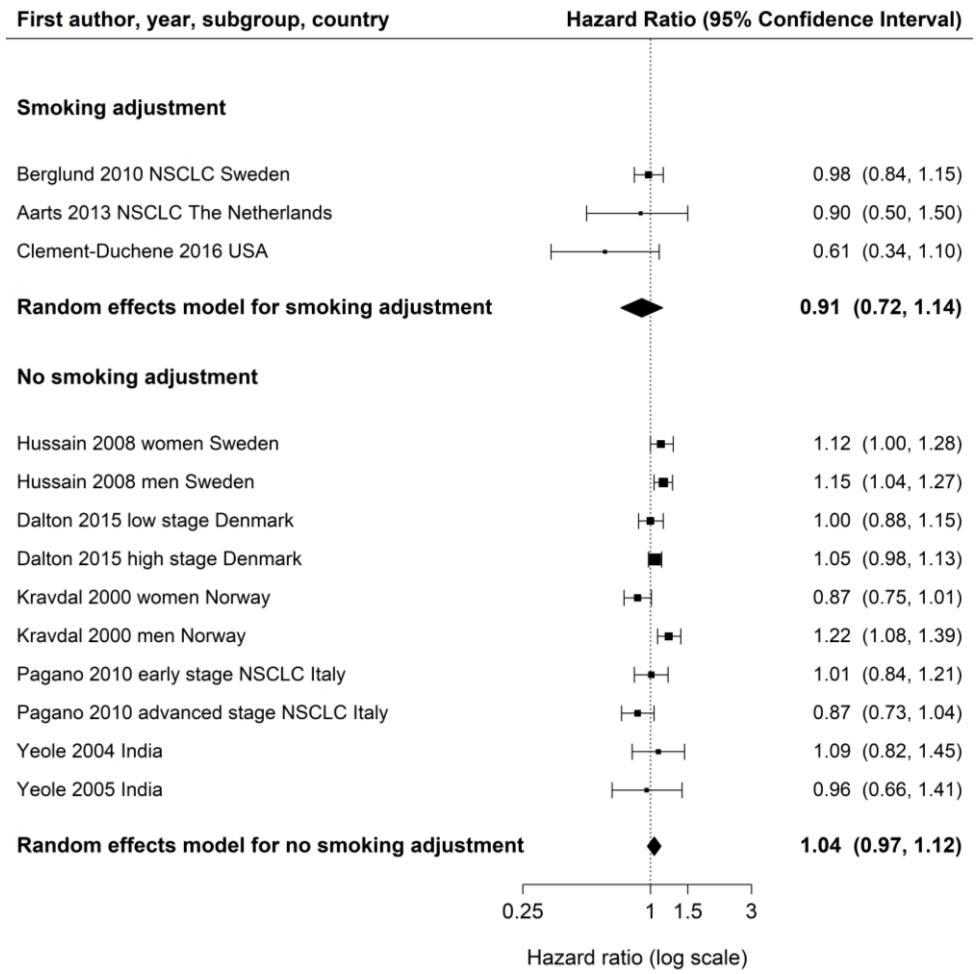

Figure A3 Meta-analysis of the association between individual education (reference: high education) and lung cancer survival stratified by smoking adjustment, order by region: Europe, USA, Asia. NSCLC = non-small cell lung cancer. Clement-Duchene 2016 included non-smokers only in their analysis.

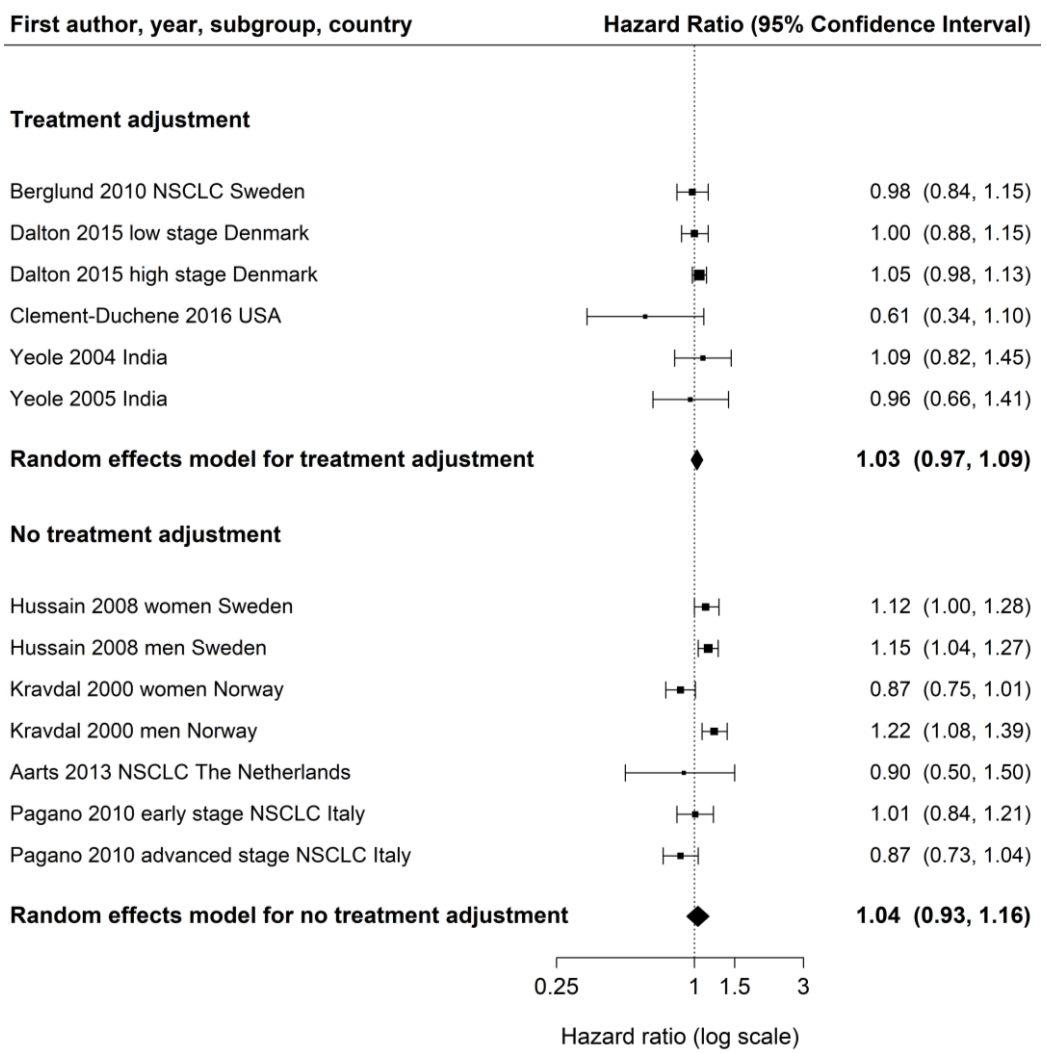

Figure A4 Meta-analysis of the association between individual education (reference: high education) and lung cancer survival stratified by treatment adjustment, order by region: Europe, USA, Asia. NSCLC = non-small cell lung cancer. Clement-Duchene 2016 included non-smokers only in their analysis.

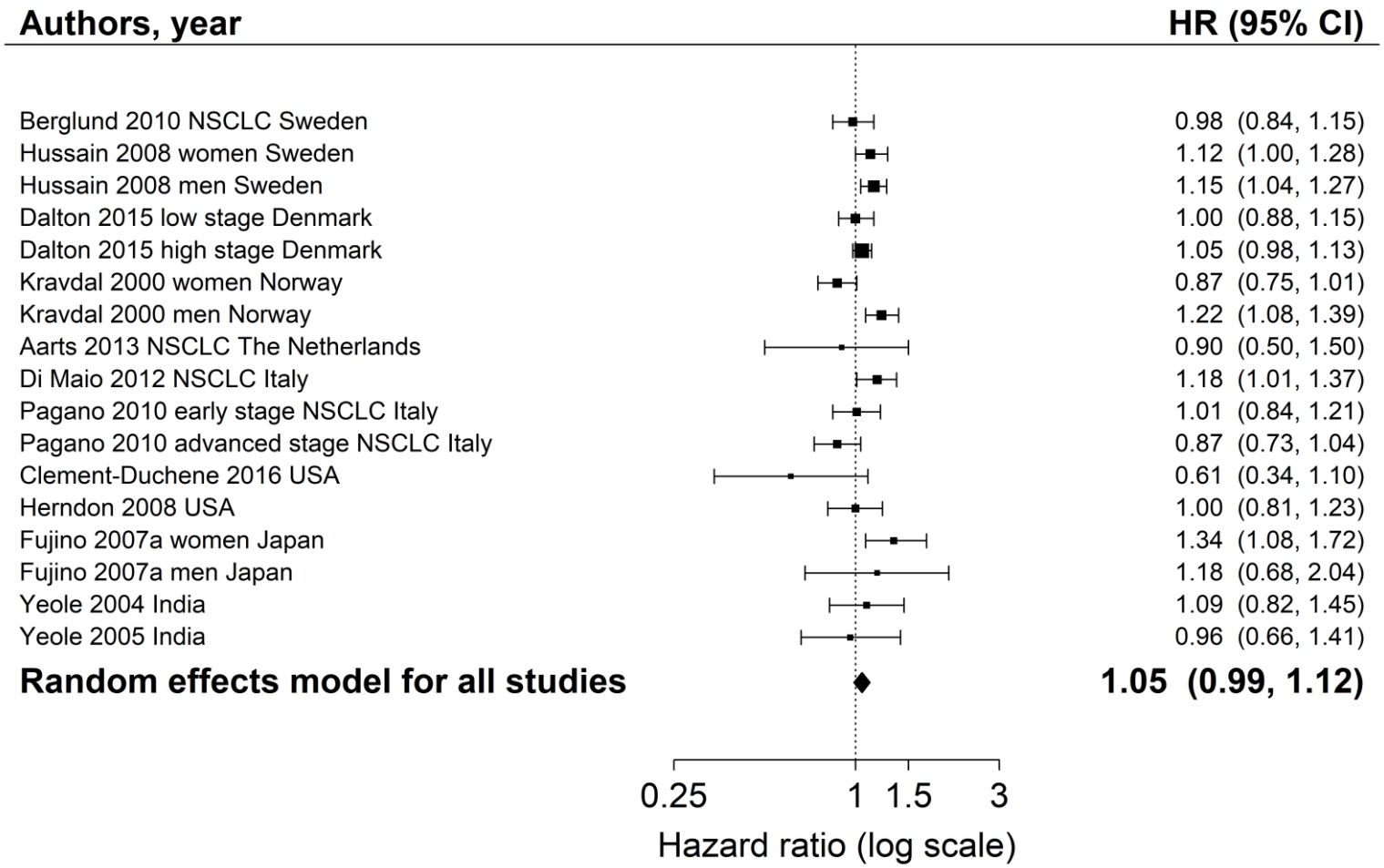

Figure A5 Sensitivity analysis: Meta-analysis of the association between individual education (reference: high education) and lung cancer survival, including three studies excluded in main analysis because of low quality score. NSCLC = non-small cell lung cancer. Kravdal 2000: highest educational group, men = 17+ years, women = 13-17+ years.

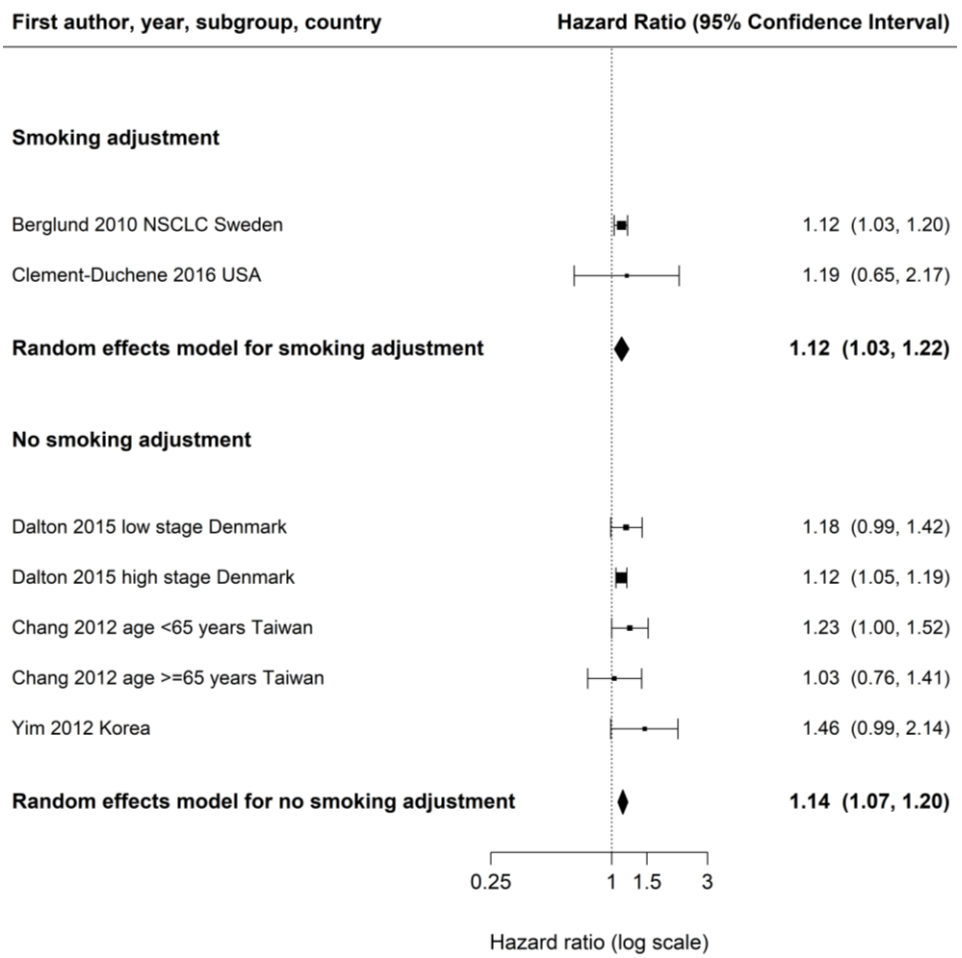

Figure A6 Meta-analysis of the association between individual income (reference: high income) and lung cancer survival stratified by smoking adjustment, order by region: Europe, USA, Asia. NSCLC = non-small cell lung cancer. Clement-Duchene 2016 included non-smokers only in their analysis.

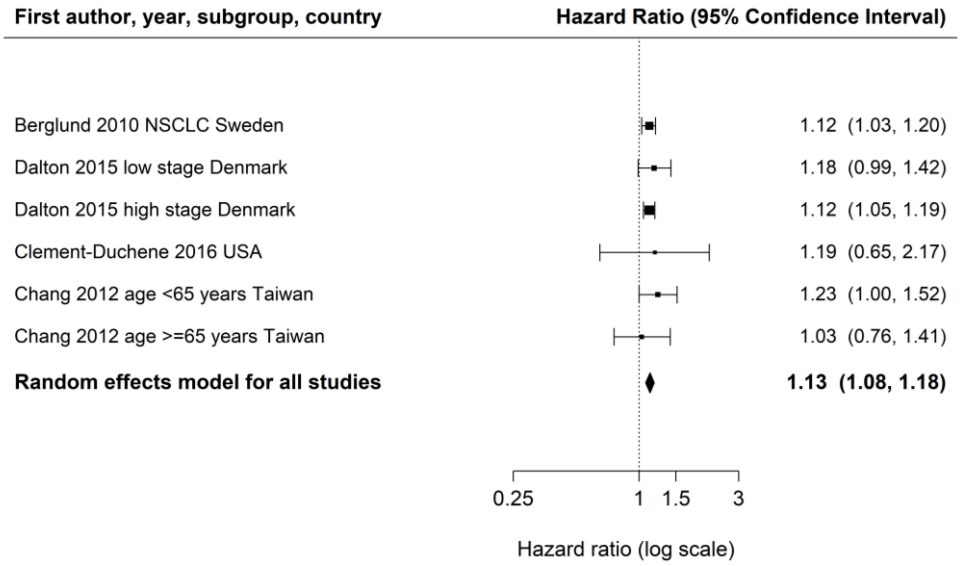

Figure A7 Meta-analysis of the association between individual income (reference: high income) and lung cancer survival including studies with treatment adjustment, order by region: Europe, USA, Asia. NSCLC = non-small cell lung cancer. Clement-Duchene 2016 included non-smokers only in their analysis.

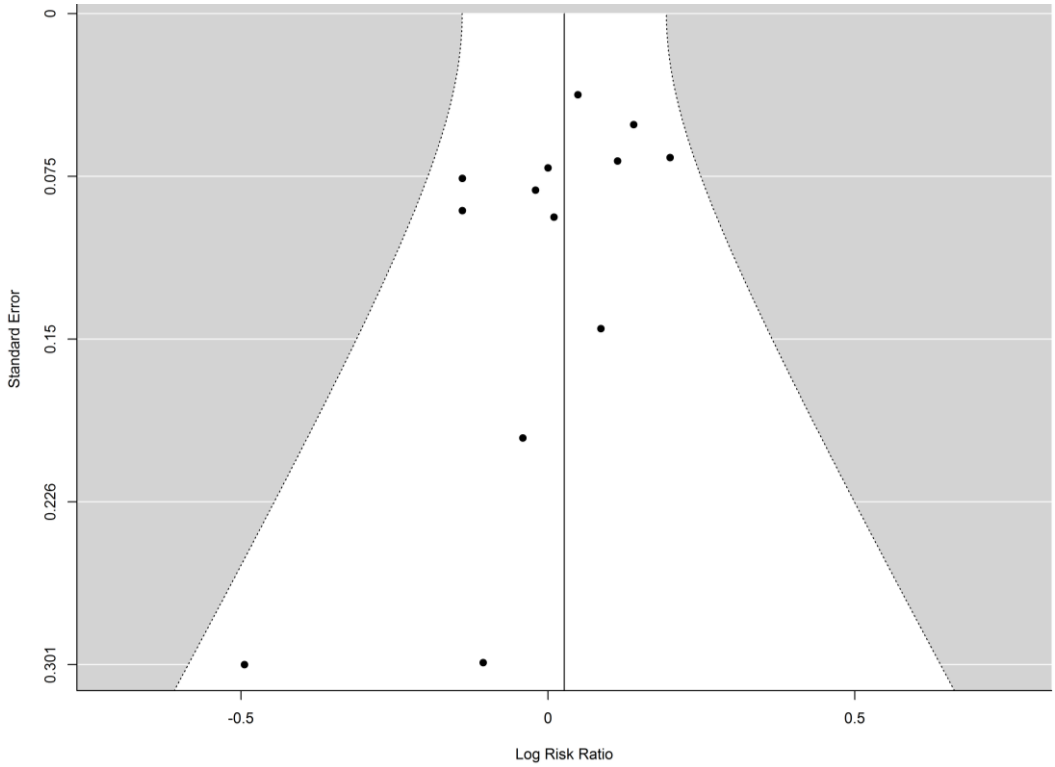

Figure A8 Funnel plot of the meta-analysis on individual education and survival after lung cancer. Begg's test: p = 0.13, Egger's test: p = 0.07.

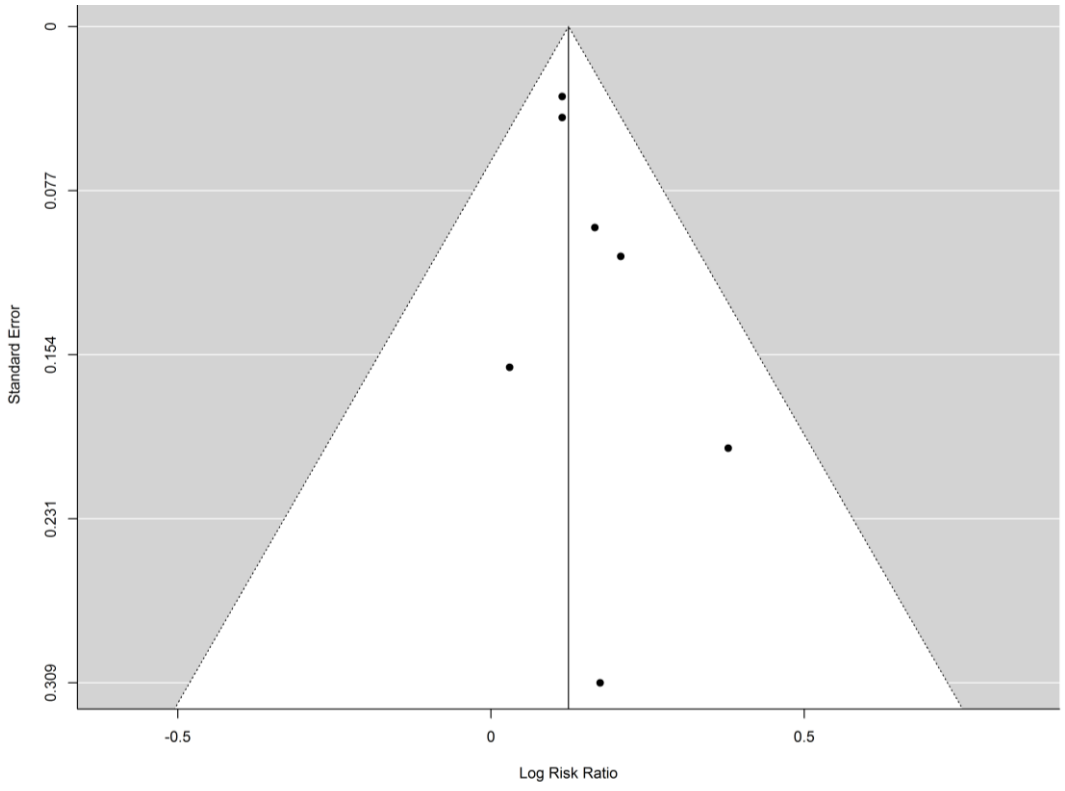

Figure A9 Funnel plot of the meta-analysis on individual income and survival after lung cancer. Begg's test: p = 0.38, Egger's test: p = 0.34.

Table A1 Association (hazard ratios) of individual measurements of socioeconomic status with survival after lung cancer.

Paper, Country	Level	Hazard Ratio (95 % Confidence Interval)[1]		
Education				
Europe, north				
(Dalton et al. 2015)		All-cause survival:		
Denmark		Low stage	High stage	
	Short	1.00 (0.88-1.15)	1.05 (0.98-1.13)	
	Medium	1.03 (0.92-1.16)	1.00 (0.94-1.05)	
	Higher	1.00	1.00	
(Kravdal 2000)		All-cause survival:		
Norway		Women		Men
	7-9 yrs	1.00		1.00
	10-12 yrs	1.04 (0.96-1.12)		**0.93 (0.89-0.97)**
	13-16 yrs	1.15 (0.99-1.34)		**0.87 (0.81-0.94)**
	17+ yrs			**0.82 (0.72-0.93)**
(Berglund et al. 2010)		Cause-specific survival:		
Sweden	Low	1.00		
	Middle	0.99 (0.89-1.09)		
	High	1.02 (0.87-1.19)		
(Hussain et al. 2008)		Cause-specific survival:		
Sweden		Women	Men	
	<9 yrs	1.00	1.00	
	9-11 yrs	0.94 (0.88-1.00)	**0.91 (0.86-0.97)**	
	12-13 yrs	**0.85 (0.77-0.94)**	**0.85 (0.80-0.90)**	
	University graduate	0.89 (0.78-1.00)	**0.87 (0.79-0.96)**	
	Linear trend	p = 0.0012	p < 0.0001	
Europe, other				
(Di Maio et al. 2012)		All-cause survival:		
Italy	Low	1.00		
	High	**0.85 (0.73-0.99)**		
(Pagano et al. 2010)		All-cause survival:		
Italy		Early stage	Advanced stage	
	Low	1.01 (0.84-1.21)	0.87 (0.73-1.04)	
	Intermediate	1.12 (0.92-1.37)	0.96 (0.79-1.16)	
	High	1.00	1.00	
	Missing	1.15 (0.91-1.46)	1.18 (0.95-1.47)	
(Aarts et al. 2013)		All-cause survival:		
The Netherlands	Level 1 (low)	0.90 (0.50-1.50)		
	Level 2	0.70 (0.40-1.20)		
	Level 3	0.80 (0.40-1.40)		
	Level 4 (high)	1.00		
USA				
(Clement-Duchene et		All-cause survival:		
al. 2016)	Some grade school	1.00		
USA	High school graduate	**1.22 (0.65-2.29)**		
	Some college or more	**2.00 (1.02-3.93)**		
(Herndon et al. 2008)		All-cause survival, unadjusted HRs[2]		
USA	Grades 1-8	1.00		
	Grades 9-11	1.04 (0.86-1.26)		
	High school graduate	1.06 (0.90-1.26)		
	Some college	0.94 (0.78-1.12)		
	College degree	1.00 (0.81-1.23)		
Asia				
(Fujino 2007a)	Age at graduation	All-cause survival:		
Japan		Women	Men	

Paper, Country	Level	Hazard Ratio (95 % Confidence Interval)[1]	
	≤15	1.00	1.00
	16-18	**0.66 (0.47-0.92)**	0.84 (0.71-1.01)
	≥19	0.85 (0.49-1.46)	**0.73 (0.58-0.93)**
(Yeole and Kumar 2004) India		All-cause survival:	
	None	1.00	
	<6yrs	0.85 (0.69-1.02)	
	6-12yrs	0.97 (0.81-1.15)	
	>12yrs	0.92 (0.69-1.22)	
	Unknown	**1.18 (1.02-1.38)**	
(Yeole 2005) India		All-cause survival:	
	None	1.00	
	<6yrs	1.05 (0.79-1.37)	
	6-12yrs	1.01 (0.79-1.30)	
	>12yrs	1.04 (0.71-1.51)	
	Unknown	1.21 (0.97-1.50)	
Income			
Europe, north			
(Dalton et al. 2015) Denmark		All-cause survival:	
		Low stage	High stage
	Low	1.18 (0.99-1.42)	**1.12 (1.05-1.19)**
	Medium	1.14 (0.99-1.32)	**1.08 (1.02-1.15)**
	High	1.00	1.00
(Berglund et al. 2010) Sweden		Cause-specific survival:	
	Low	1.00	
	High	**0.89 (0.83-0.97)**	
USA			
(Clement-Duchene et al. 2016) USA		All-cause survival:	
	< $20000	1.00	
	$20000-$40000	0.82 (0.45-1.46)	
	$40000-$60000	0.71 (0.32-1.57)	
	$60000 or more	0.56 (0.26-1.20)	
(Greenwald et al. 1994) USA	Model 1 (only individual)		
	Income (continuous)	**0.82 (0.71-0.95)** per $5000 (yearly income)	
Asia			
(Yim et al. 2012) Korea		Cause-specific survival:	
	Low	1.46 (0.99-2.14)	
	Middle	1.11 (0.78-1.57)	
	High	1.00	
(Chang et al. 2012) Taiwan		All-cause survival:	
	Age <65 yrs	Advantaged Neighborhood	Disadvantaged Neighborhood
	Low	**1.36 (1.10–1.67**)	1.23 (1.00–1.52)
	Moderate	1.13 (0.90-1.42)	1.24 (0.96–1.60)
	High	1.00	0.91 (0.68–1.22)
	Age ≥ 65 yrs		
	Low	0.92 (0.67–1.26)	1.03 (0.76–1.41)
	Moderate	1.03 (0.72–1.48)	0.84 (0.55–1.29)
	High	1.00	0.83 (0.51–1.37)
Occupation			
Europe, north			
(Berglund et al. 2010) Sweden		Cause-specific survival:	
	Low	1.00	
	High	0.93 (0.85-1.01)	
	Unknown	1.11 (0.79-1.57)	

Paper, Country	Level	Hazard Ratio (95 % Confidence Interval)[1]	
(Kravdal 2000)		Occupation (combined with education), only men	
Norway		All-cause survival:	
	Low education (7-12 yrs)		
	Manual (exept §)	1.00	
	Non-manual (exept §)	**0.96***	
	§: hotel and restaurant workers, ship´s officers, deck and engine-room crew	**0.92***	
	Farmer	**1.08***	
	Fisherman	0.97	
	No occupation recorded	**1.18***	
	Medium education (13-16 yrs)		
	(Largely) manual	1.15	
	Non-manual, low level	0.95	
	Non-manual, high level	**0.84***	
	Teacher	0.93	
	High education (17+ yrs)		
	Teacher	0.90	
	Physician	0.73	
	Other groups	**0.85***	
	Medium or high education		
	No occupation recored	0.68	
		*p<0.05	
Asia			
(Fujino 2007b)		All-cause survival:	
Japan		Women	Men
	Type of employment		
	Employed	1.00	1.00
	Part time	1.11 (0.43-2.82)	1.44 (0.91-2.28)
	Self-employed	1.83 (0.89-3.76)	1.13 (0.91-1.41)
	Housewife	**2.09 (1.05-4.13)**	1.25 (0.17-8.97)
	Unemployed	**2.13 (1.04-4.38)**	1.12 (0.87-1.45)
	Others	2.18 (0.94-5.06)	1.17 (0.84-1.62)
	Type of jobs (1)		
	Office work	1.00	1.00
	Manual work	0.58 (0.32-1.06)	1.07 (0.83-1.36)
	Others	0.72 (0.36-1.40)	1.18 (0.82-1.70)
	Type of jobs (2)		
	Sedentary work	1.00	1.00
	Sedentary and standing	0.95 (0.57-1.57)	0.96 (0.74-1.26)
	Standing position	0.39 (0.13-1.11)	0.86 (0.58-1.29)
	Moving	0.96 (0.62-1.47)	1.06 (0.86-1.31)

[1]unless otherwise noted, fully adjusted model; [2]Multivariable HRs including education were not significant (results not shown in article); Abbreviations: CI = Confidence interval; HR = Hazard ratio; mths = Months; NA = Not available; NSCLC = Non-small cell lung cancer; yrs = Years of age

Table A2 Association (hazard ratios) of aggregated measurements of socioeconomic status with survival after lung cancer.

Paper,Country,SES level	Level	Hazard Ratio (95 % Confidence Interval)[1]		
Education				
USA				
(Johnson et al. 2014)		All-cause survival:		
USA		Stage I and II	Stage III	
Census tract	Q4 (low)	**1.36 (1.24-1.50)**	**1.13 (1.02-1.25)**	
	Q3	**1.17 (1.07-1.29)**	**1.12 (1.02-1.23)**	
	Q2	**1.18 (1.08-1.29)**	**1.17 (1.07-1.28)**	
	Q1 (high)	1.00	1.00	
(Johnson et al. 2016)		All-cause survival:		
USA	Q4 (low)	**1.30 (1.16-1.46)**		
Census tract	Q3	**1.13 (1.01-1.26)**		
	Q2	**1.12 (1.01-1.24)**		
	Q1 (high)	1.00		
(Khullar et al. 2015)	No high school	All-cause survival:		
USA	≥29 %	**1.11 (1.06-1.16)**		
Zip code	20-28.9 %	**1.06 (1.02-1.09)**		
	14-19.9 %	**1.05 (1.02-1.08)**		
	<14 %	1.00		
Income				
Europe				
(Berglund et al. 2012)		All-cause survival:		
England		Early-stage NSCLC	Stage III disease	Advanced disease/SCLC
Lower super output area	Q5 (low)	1.24 (0.98-1.56)	**1.16 (1.01-1.34)**	**1.12 (1.05-1.20)**
	Q4	1.15 (0.91-1.46)	1.15 (1.00-1.32)	**1.16 (1.08-1.25)**
	Q3	1.18 (0.93-1.51)	1.14 (0.99-1.32)	**1.13 (1.05-1.22)**
	Q2	1.09 (0.85-1.40)	**1.20 (1.03-1.39)**	**1.17 (1.08-1.26)**
	Q1 (high)	1.00	1.00	1.00
		Trend p = 0.11	p = 0.70	p = 0.17
Canada/USA				
(Mackillop et al. 1997)		Cause-specific survival:		
Canada	<$20000	**1.13 (1.06-1.22)**		
Postal code	$20000-$30000	**1.14 (1.08-1.21)**		
	$30000-$40000	**1.14 (1.08-1.22)**		
	$40000-$50000	**1.10 (1.03-1.17)**		
	>$50000	1.00		
	p Trend	**1.10 (1.07-1.14)**		
(Booth et al. 2010)		All-cause survival:		
Canada	Q1 (low)	**1.09 (1.02-1.16)**		
Community	Q2	1.05 (0.98-1.12)		
	Q3	1.03 (0.96-1.10)		
	Q4	0.98 (0.91-1.05)		
	Q5 (high)	1.00		
(Dabbikeh et al. 2017)	Constant dollar	All-cause survival:		
Canada	(per $10000)	1.00 (p = 0.60)		
Enumeration/ dissemination area				
(Boyd et al. 1999)		Cause-specific survival:		
Canada/USA		Canada	USA	
USA: census tract	Q5 (low)	**1.04 (1.01-1.08)**	**1.13 (1.10-1.16)**	
Canada: enumeration	Q4	1.04 (1.00-1.07)	**1.05 (1.02-1.08)**	
area	Q3	1.01 (0.98-1.05)	1.00 (ref)	
	Q2	0.98 (0.94-1.02)	**0.95 (0.93-0.98)**	
	Q1 (high)	**0.93 (0.89-0.98)**	**0.93 (0.90-0.96)**	
		p < 0.0001		

Paper,Country,SES level	Level	Hazard Ratio (95 % Confidence Interval)[1]	
(Zhang-Salomons et al. 2006)		Cause-specific survival: Canada	USA
Canada/USA	Income (quintiles)		
Census tract	Q1 (low)	**1.13**	**1.39**
	Q5 (high)	1.00	1.00
	Poverty (quintiles)		
	Q1 (high)	1.07	**1.38**
	Q5 (low)	1.00	1.00
	Poverty (tertile)		
	T1 (high)	1.05	**1.29**
	T3 (low)	1.00	1.00
(Khullar et al. 2015)		All-cause survival:	
USA	<$30000	**1.08 (1.03-1.13)**	
Zip code	$30000-$34999	**1.07 (1.03-1.11)**	
	$35000-45999	**1.05 (1.02-1.09)**	
	$46000+	1.00	
(McMillan et al. 2017)		All-cause survival:	
USA	<$63000	1.00	
Zip code	≥$63000	**0.94 (0.89-0.99)**	
	Unknown	**1.74 (1.53-1.98)**	
(Greenwald et al. 1994)	Model 2	All-cause survival:	
USA	(only census tract)		
Census tract	Median income	0.87 (0.65-1.15) per US$5000 increment	
	Model 3 (both individual and census tract)		
	Individual income	**0.82 (0.71-0.95)** per US$5000 increment	
	Median income	1.01 (0.77-1.32)	
(Greenwald et al. 1998)		All-cause survival:	
USA	Median income	HR = **0.98 (p < 0.0003)** per decile increase	
Census tract			
(Johnson et al. 2014)		All-cause survival:	
USA		Stage I and II	Stage III
Census tract	Q4 (low)	1.03 (0.94-1.12)	**1.12 (1.03-1.23)**
	Q3	1.06 (0.97-1.15)	**1.10 (1.01-1.20)**
	Q2	1.08 (1.00-1.17)	1.08 (0.99-1.18)
	Q1 (high)	1.00	1.00
		(patients who died within 2 weeks of diagnosis excluded, n = 1889)	
(Johnson et al. 2016)		All-cause survival:	
USA	Q4 (low)	1.06 (0.94-1.18)	
Census tract	Q3	1.05 (0.96-1.15)	
	Q2	1.04 (0.96-1.13)	
	Q1 (high)	1.00	
(Niu et al. 2010)		Cause-specific survival:	
USA	Poverty level	Men	Women
Census tract	≥20 %	**1.23 (1.15-1.31)**	**1.18 (1.09-1.28)**
	10-20 %	**1.09 (1.04-1.14)**	**1.12 (1.06-1.18)**
	5-10 %	1.05 (1.00-1.09)	1.04 (0.99-1.09)
	<5 %	1.00	1.00
(Shugarman et al. 2008)		All-cause survival:	
USA	<$29 000	1.00	
Census tract	$29 000-41 000	0.98	
	>$41 000	0.95	
		p < 0.05	
(Tannenbaum et al. 2014)		All-cause survival:	
USA	Low	1.00	
	Middle-low	**0.96 (0.94-0.99)**	

Paper,Country,SES level	Level	Hazard Ratio (95 % Confidence Interval)[1]
Census tract	Middle-high	**0.92 (0.89-0.94)**
	High	**0.87 (0.84-0.91)**
(Yang et al. 2010)	Poverty level	All-cause survival:
USA	≥15 %	**1.05 (1.02-1.09)**
Census tract	10-15 %	1.03 (1.00-1.06)
	5-10 %	1.01 (0.98-1.03)
	<5 %	1.00
(Wang et al. 2017a)	Poverty	Cause-specific survival:
USA	Medium-high	**1.06 (1.06-1.07)**
County	Low	1.00
(Wang et al. 2017b)	Poverty	Cause-specific survival:
USA	Medium-high	**1.07 (1.06-1.08)**
County	Low	1.00
Australia		
(Bonett et al. 1984)		No difference in CSS by income (results not shown in article)
Australia		
Collection district		
Index		
Europe		
(Chouaid et al. 2017)		1-year all-cause survival
France		Non-Metastatic disease / Metastatic disease
Commune	Q1 (low)	**1.25 (1.16-1.35)** / **1.19 (1.13-1.26)**
	Q2	**1.19 (1.10-1.29)** / **1.13 (1.07-1.20)**
	Q3	**1.14 (1.05-1.24)** / **1.11 (1.04-1.18)**
	Q4 (high)	1.00 / 1.00
		2-year all-cause survival
		Non-Metastatic disease / Metastatic disease
	Q1 (low)	**1.21 (1.13-1.30)** / **1.19 (1.13-1.25)**
	Q2	**1.15 (1.08-1.23)** / **1.14 (1.08-1.20)**
	Q3	**1.10 (1.03-1.18)** / **1.10 (1.04-1.16)**
	Q4 (high)	1.00 / 1.00
(Aarts et al. 2015)		All-cause survival:
The Netherlands	Low	1.00
Postal code	Intermediate	0.90 (0.90-1.00)
	High	0.92 (0.85-0.99)[2]
	Institutionalized	1.00 (0.80-1.10)
	Unknown	0.90 (0.70-1.00)
(Louwman et al. 2010)		All-cause survival:
The Netherlands		Men / Women
Postal code	Lowest SES	1.11 (1.0-1.2) / 1.09 (1.0-1.2)
	Highest SES	1.00 / 1.00
(Schrijvers et al. 1995a)		All-cause survival:
The Netherlands	Q5 (low)	**1.16 (1.03-1.31)**
Postal code	Q4	**1.15 (1.02-1.30)**
	Q3	1.07 (0.94-1.21)
	Q2	1.02 (0.87-1.19)
	Q1 (high)	1.00
	Trend	**1.04 (1.01-1.07)**
(Iyen-Omofoman et al. 2011)		All-cause survival, HR unadjusted
	Q5 (low)	1.01 (0.94-1.09)
United Kingdom	Q4	0.94 (0.88-1.01)
Output area	Q3	1.03 (0.96-1.10)
	Q2	0.98 (0.91-1.05)
	Q1 (high)	1.00

Paper,Country,SES level	Level	Hazard Ratio (95 % Confidence Interval)[1]	
	Missing	**0.78 (0.68-0.88)**	
(Schrijvers et al. 1995b)		All-cause survival:	
England	Q5 (low)	1.11 (1.00-1.23)	
Enumeration district	Q4	**1.13 (1.04-1.22)**	
	Q3	**1.09 (1.01-1.18)**	
	Q2	1.04 (0.96-1.12)	
	Q1 (high)	1.00	
(Rich et al. 2011)		All-cause survival:	
England	Q5 (low)	1.00 (0.95-1.06)	
Lower super output area	Q4	1.03 (0.99-1.06)	
	Q3	1.02 (0.99-1.05)	
	Q2	1.03 (1.00-1.06)	
	Q1 (high)	1.00	
Canada/USA			
(Dabbikeh et al. 2017)		All-cause survival:	
Canada	Q1 (low)	1.00 (p = 0.80)	
Enumeration/	Q2	0.97 (p = 0.19)	
dissemination area	Q3	0.99 (p = 0.70)	
	Q4	0.97 (p = 0.23)	
	Q5 (high)	1.00	
(Gomez et al. 2016)		All-cause survival:	
USA		Men	Women
Census block group	Q1 (low)	1.16 (0.98-1.38)	**1.38 (1.10-1.72)**
	Q2	1.12 (0.95-1.32)	**1.22 (1.01-1.47)**
	Q3	1.11 (0.95-1.28)	1.18 (0.98-1.41)
	Q4	1.06 (0.93-1.22)	0.97 (0.82-1.15)
	Q5 (high)	1.00	1.00
(Hastert et al. 2015)		Cause-specific survival:	
USA	Q1 (low)	**2.21 (1.69-2.90)**	
Census block group	Q2	**2.00 (1.51-2.65)**	
	Q3	**1.64 (1.22-2.19)**	
	Q4	**1.62 (1.21-2.17)**	
	Q5 (high)	1.00	
	Trend	p<0.001	
(Lara et al. 2017)		Cause-specific survival:	
USA	Low SES (Q1-Q3)	**1.05 (1.02-1.09)**	
Census block group	High SES (Q4, Q5)	1.00	
(Ou et al. 2007)		All-cause survival:	
USA		Stage IA	Stage IB
Census block group	Q1 (low)	1.00	1.00
	Q2	0.91 (0.81-1.03)	**0.91 (0.82-1.00[3])**
	Q3	**0.87 (0.78-0.98)**	**0.90 (0.81-0.98)**
	Q4	**0.76 (0.68-0.86)**	**0.86 (0.78-0.94)**
	Q5 (high)	**0.79 (0.70-0.89)**	**0.75 (0.68-0.82)**
(Ou et al. 2008)		All-cause survival:	
USA	Q1 (low)	1.00	
Census block group	Q2	**0.91 (0.85-0.98)**	
	Q3	**0.90 (0.84-0.97)**	
	Q4	**0.83 (0.77-0.89)**	
	Q5 (high)	**0.78 (0.72-0.84)**	
(Ou et al. 2009)		All-cause survival:	
USA		**0.97 (0.94-0.99)** (increase per SES score)	
Census block group		p (trend) = 0.01	
(Lara et al. 2014)		Cause-specific survival:	
USA	Lowest SES	1.00	
Census tract	Mid SES	**0.96 (0.94-0.98)**	
	Highest SES	**0.90 (0.89-0.92)**	

Paper,Country,SES level	Level	Hazard Ratio (95 % Confidence Interval)[1]
(Wen and Christakis 2005)[4] USA Zip code	Social index	Cause-specific survival: 1.02 (0.94-1.10)[5]
Australia/New Zealand		
(Hall et al. 2004)		All-cause survival:
Australia	Q5 (low)	1.05 (0.93-1.20)
Collection district	Q4	1.03 (0.92-1.15)
	Q3	1.09 (0.98-1.20)
	Q2	1.03 (0.92-1.16)
	Q1 (high)	1.00
(Tervonen et al. 2017)		SHR (95 % CI) full model, all-cause survival
Australia		SLA / CD
Collection district and	Q5 (low)	**1.14 (1.08-1.19)** / **1.21 (1.15-1.27)**
Statistical local area	Q4	**1.15 (1.09-1.21)** / **1.13 (1.08-1.19)**
	Q3	**1.13 (1.08-1.19)** / **1.10 (1.05-1.16)**
	Q2	1.06 (1.00-1.11) / **1.06 (1.01-1.12)**
	Q1 (high)	1.00 / 1.00
(Currow et al. 2014)		SHR (CSS, 95 % CI) full model, all-cause survival
Australia	Q5 (low)	1.24 (0.97-1.59)
Postal code area	Q4	1.19 (0.94-1.52)
	Q3	1.00 (0.79-1.27)
	Q2	1.02 (0.82-1.28)
	Q1 (high)	1.00
(Denton et al. 2017)		All-cause survival:
Australia	Q1 (low)	1.10 (0.89-1.30)
Postal code area	Q2	1.00 (0.84-1.20)
	Q3	1.00 (0.83-1.20)
	Q4	1.00 (0.85-1.20)
	Q5 (high)	1.00
(Haynes et al. 2008)		All-cause survival:
New Zealand	Low	1.00
Census area unit	Medium	1.06
	High	**1.11** (p<0.05)
	Highest	**1.21** (p<0.01)
Asia		
(Kwak and Kim 2017)		All-cause survival:
Korea	Q4 (low)	1.06 (0.87–1.30)
Dong	Q3	1.18 (1.00–1.40)
	Q2	1.01 (0.87–1.17)
	Q1 (high)	1.00
(Kwak 2017)		Cause-specific survival:
Korea	Q4 (low)	**1.08 (1.01-1.15)**
Dong	Q3	**1.11 (1.05-1.17)**
	Q2	**1.08 (1.03-1.13)**
	Q1 (high)	1.00

[1]unless otherwise noted, fully adjusted model; [2]according to correspondence with author; [3]upper limit of the confidence interval is 0.995; [4]approximated from figure in paper;[5]derived from log scale; CD = Census collection district; CI = Confidence interval; CSS = Cause-specific survival; HR = Hazard ratio; NSCLC = Non-small cell lung cancer; RS =Relative survival; SEIFA = Socioeconomic indexes for areas; SES = Socioeconomic status; SLA = Statistical local area

Table A3 Risk of bias assessment for cohort studies according to a modified Newcastle-Ottawa-Scale.

SES Level	Paper	Representative-ness of the exposed cohort[a]	Ascertainment of exposure[b]	Demonstration that outcome of interest was not present at the start of study[c]	Comparability of cohort on the basis of the design or analysis[d]	Assessment of outcome[e]	Was FU long enough for outcomes to occur[f]	Adequacy of FU's of cohorts[g]	Total score
Individual	(Aarts et al. 2013)	1	0	1	2	1	1	1	7
	(Berglund et al. 2010)	1	1	1	2	1	1	1	8
	(Chang et al. 2012)	1	1	1	2	1	1	1	8
	(Chirikos et al. 1984)	1	1	1	2	1	1	1	8
	(Clement-Duchene et al. 2016)	1	1	1	2	1	1	1	8
	(Dalton et al. 2008)	1	1	1	2	1	1	1	8
	(Dalton et al. 2015)	1	1	1	2	1	1	1	8
	(Di Maio et al. 2012)	0	1	0	2	0	1	0	4
	(Fujino 2007a)	0	0	0	2	1	1	1	5
	(Fujino 2007b)	0	0	0	2	1	1	1	5
	(Grivaux et al. 2011)	0	0	1	0	1	1	1	4
	(Herndon et al. 2008)	0	0	0	0	0	1	0	1
	(Hussain et al. 2008)	1	1	1	2	1	1	1	8
	(Kravdal 2000)	1	1	1	2	1	1	1	8
	(Pagano et al. 2010)	1	1	1	2	1	1	1	8
	(Pastorino et al. 1990)	1	1	1	0	1[h]	1	1	6
	(Pokhrel et al. 2010)	1	1	1	2	1	1	1	8
	(Skyrud et al. 2016)	1	1	1	2	1[h]	1	1[h]	8
	(Smailyte et al. 2016)	1	1	1	2	1	1	1	8
	(Vågerö and Persson 1987)	1	1	1	1	1[h]	1	1[h]	7
	(Yeole and Kumar 2004)	1	1	1	2	1	1	1	8
	(Yeole 2005)	1	1	1	2	1	1	1	8
	(Yim et al. 2012)	0	1	1	2	1	1	1	7
Aggregated	(Aarts et al. 2015)	1	1	1	2	1	1	1	8
	(Berglund et al. 2012)	1	1	1	2	1	1	1	8
	(Bonett et al. 1984)	1	1	1	2	1	1	1	8
	(Booth et al. 2010)	1	1	1	2	1[h]	1	1[h]	8

SES Level	Paper	Representative-ness of the exposed cohort[a]	Ascertainment of exposure[b]	Demonstration that outcome of interest was not present at the start of study[c]	Comparability of cohort on the basis of the design or analysis[d]	Assessment of outcome[e]	Was FU long enough for outcomes to occur[f]	Adequacy of FU's of cohorts[g]	Total score
Aggregated	(Boyd et al. 1999)	1	1	1	2	1	1	1	8
	(Campbell et al. 2000)	1	1	1	2	1[h]	1	1[h]	8
	(Caposole et al. 2014)	1	1	1	1	1	1	0	6
	(Cheyne et al. 2013)	0	1	1	0	1	1	0	4
	(Chouaid et al. 2017)	1	1	1	2	1	1	0	7
	(Coleman et al. 2001)	1	1	1	1	1	1	1	7
	(Coleman et al. 2004)	1	1	1	1	1	1	1	7
	(Currow et al. 2014)	1	1	1	2	1	1	1	8
	(Dabbikeh et al. 2017)	1	1	1	2	1	1	1	8
	(Denton et al. 2017)	0	1	1	2	1	1	1	7
	(Ellis et al. 2014)	1	1	1	2	1	1	1	8
	(Erhunmwunsee et al. 2012)	1	1	1	0	0	1	1	5
	(Evans and Pritchard 2000)	1	1	1	2	1	1	1	8
	(Forrest et al. 2015)	1	1	1	2	1[h]	1	1[h]	8
	(Gomez et al. 2016)	1	1	1	2	1	1	1	8
	(Gorey et al. 1997)	1	1	1	2	1[h]	1	1[h]	8
	(Greenwald et al. 1994)	1	1	1	2	1	1	1	8
	(Greenwald et al. 1998)	1	1	1	2	1	1	1	8
	(Hall et al. 2004)	1	1	1	2	1	1	1	8
	(Hastert et al. 2015)	1	1	1	2	1	1	1	8
	(Haynes et al. 2008)	1	1	1	2	1	1	1	8
	(Hui et al. 2005)	1	1	1	0	1	1	1	6
	(Ito et al. 2014)	1	1	1	1	1	1	1	7
	(Iyen-Omofoman et al. 2011)	1	1	1	0	1	1	1	6
	(Jack et al. 2006)	1	1	1	2	1	1	1	8
	(Jansen et al. 2014)	1	1	1	2	1	1	1	8
	(Jeffreys et al. 2009)	1	1	1	1	1	1	1	7

SES Level	Paper	Representative-ness of the exposed cohort[a]	Ascertainment of exposure[b]	Demonstration that outcome of interest was not present at the start of study[c]	Comparability of cohort on the basis of the design or analysis[d]	Assessment of outcome[e]	Was FU long enough for outcomes to occur[f]	Adequacy of FU's of cohorts[g]	Total score
Aggregated	(Johnson et al. 2014)	1	1	1	2	1	1	1	8
	(Johnson et al. 2016)	1	1	1	2	1	1	1[i]	8
	(Khullar et al. 2015)	1	1	1	2	1	1	1[k]	8
	(Kwak and Kim 2017)	1	1	1	2	1	1	1	8
	(Kwak 2017)	1	1	1	2	1	1	1	8
	(Lara et al. 2014)	1	1	1	2	1[m]	1	1[m]	8
	(Lara et al. 2017)	1	1	1	2	1[m]	1	1[m]	8
	(Lipworth et al. 1970)	1	1	1	1	0	1	0	5
	(Louwman et al. 2010)	1	1	1	2	1[h]	1	1[h]	8
	(Mackillop et al. 1997)	1	1	1	2	1	1	1	8
	(McMillan et al. 2017)	1	1	1	2	1	1	1	8
	(Melvan et al. 2015)	1	1	1	0	1	1	1	6
	(Niu et al. 2010)	1	1	1	2	1	1	1	8
	(Nur et al. 2015)	1	1	1	2	1	1	1	8
	(O'Dowd et al. 2015)	1	1	1	0	1	1	1	6
	(Ou et al. 2007)	1	1	1	2	1	1	1	8
	(Ou et al. 2008)	1	1	1	2	1[n]	1	1	8
	(Ou et al. 2009)	1	1	1	2	0	1	1	7
	(Pollock and Vickers 1997)	1	1	1	2	1[h]	1	1[h]	8
	(Rachet et al. 2008)	1	0	1	1	1[h]	1	1[h]	6
	(Rachet et al. 2010)	1	1	1	2	1[h]	1	1	8
	(Riaz et al. 2011)	1	1	1	1	1[h]	1	1[h]	7
	(Rich et al. 2011)	1	1	1	2	1	1	1	8
	(Schrijvers et al. 1995a)	1	1	1	2	1	1	1	8
	(Schrijvers et al. 1995b)	1	1	1	2	1[h]	1	1[h]	8
	(Shack et al. 2007)	1	1	1	2	1	1	1	8
	(Shugarman et al. 2008)	1	1	1	2	1[m]	0	1[m]	7
	(Sloggett et al. 2007)	1	1	1	2	1	1	1	8

SES Level	Paper	Representative-ness of the exposed cohort[a]	Ascertainment of exposure[b]	Demonstration that outcome of interest was not present at the start of study[c]	Comparability of cohort on the basis of the design or analysis[d]	Assessment of outcome[e]	Was FU long enough for outcomes to occur[f]	Adequacy of FU's of cohorts[g]	Total score
Aggregated	(Stanbury et al. 2016a)	1	1	1	2	1	1	1	8
	(Sutherland and Aitken 2008)	1	1	1	0	0	1	0	4
	(Tannenbaum et al. 2014)	1	1	1	2	1	1	1	8
	(Tervonen et al. 2017)	1	1	1	2	1	1	1	8
	(Vercelli et al. 2006)	1	1	1	1	1[h]	1	1[h]	7
	(Wang et al. 2017a)	1	1	1	2	1[m]	1	1[m]	8
	(Wang et al. 2017b)	1	1	1	2	1[m]	1	1[m]	8
	(Wen and Christakis 2005)	1	1	1	0	1	1	1	6
	(Yang et al. 2010)	1	1	1	2	1[o]	1	1[o]	8
	(Yu et al. 2008)	1	1	1	2	1	1	1	8
	(Yu et al. 2014)	1	1	1	1	1[m]	1	1[m]	7
	(Zhang-Salomons et al. 2006)	1	1	1	2	1[h]	1	1[h]	8

Abbreviations: FU = Follow-up; SES=Socioeconomic status; [a]If the study was population-based, a point was assigned; [b]If socioeconomic status was assessed by official statistics/registry/census, the study was awarded with one point; [c]If the study is based on data by a cancer registry, one point was assigned, as only incident cases were registered, other studies were assigned with one point if it was reported that only incident cases were included; [d]If the study adjusted for at least age one point was assigned. If the analyses were adjusted for additional factors like gender, stage or smoking one additional point was assigned; [e]If there was independent/blind assessment of outcome (survival), record linkage or authors explained how the outcome was assessed, one point was assigned; [f]If follow-up was at least as long as the shortest survival rate (for example 3 months) that was reported in article, one point was assigned; [g]If FU rate ≥90 % or information was ascertained through registration or other administrative offices, one point was assigned; [h]Information was not given in article but registry is part of EUROCARE or GLOBOCAN; [i]As stated in Johnson 2014; [k]As stated in McMillan 2017; [m]Study is part of The Surveillance, Epidemiology, and End Results Program; [n]As stated in Ou 2007; [o]As stated in Tannenbaum 2014

Supplementary material, analyses of clinical cancer registries (lung cancer)

Table A4 Adjusted[a] survival rates stratified by area-based socioeconomic deprivation and by patient and tumor characteristics for the total population of lung cancer patients registered in three German clinical cancer registries.

Area-based socioeconomic deprivation quintile	Overall Survival in % (95 % Confidence Interval)		
	1 year	3 years	5 years
Total population			
Q1 (=least deprived)	49.6 (48.4-50.8)	23.6 (22.6-24.6)	17.1 (16.2-18.0)
Q2	49.1 (47.9-50.2)	23.1 (22.2-24.1)	16.7 (15.9-17.5)
Q3	49.0 (47.9-50.1)	23.1 (22.2-24.1)	16.7 (15.9-17.5)
Q4	48.3 (47.1-49.4)	22.5 (21.5-23.4)	16.1 (15.3-17.0)
Q5 (=most deprived)	**47.9 (46.8-48.9)**	**22.1 (21.3-23.0)**	**15.9 (15.1-16.7)**
Men			
Q1 (=least deprived)	47.9 (46.5-49.3)	22.0 (20.8-23.2)	15.7 (14.7-16.7)
Q2	47.0 (45.7-48.3)	21.3 (20.2-22.4)	15.1 (14.2-16.0)
Q3	46.8 (45.5-48.1)	21.2 (20.1-22.2)	15.0 (14.1-15.9)
Q4	46.1 (44.8-47.4)	20.6 (19.6-21.7)	14.5 (13.6-15.4)
Q5 (=most deprived)	**45.6 (44.3-46.8)**	**20.1 (19.2-21.1)**	**14.1 (13.3-15.0)**
Women			
Q1 (=least deprived)	54.0 (51.7-56.2)	27.6 (25.5-29.7)	20.7 (18.9-22.5)
Q2	54.6 (52.5-56.6)	28.1 (26.2-30.0)	21.1 (19.4-22.8)
Q3	55.2 (53.1-57.3)	28.7 (26.8-30.7)	21.6 (19.9-23.4)
Q4	**53.8 (51.6-55.9)**	**27.4 (25.5-29.4)**	**20.5 (18.8-22.3)**
Q5 (=most deprived)	54.2 (52.0-56.3)	27.8 (25.8-29.8)	20.8 (19.1-22.6)
Age 15-69 years			
Q1 (=least deprived)	52.8 (51.2-54.3)	25.8 (24.5-27.2)	19.7 (18.5-20.9)
Q2	53.5 (52.0-54.9)	26.5 (25.1-27.8)	20.2 (19.1-21.4)
Q3	53.5 (52.0-54.9)	26.4 (25.1-27.8)	20.2 (19.1-21.4)
Q4	52.2 (50.7-53.7)	25.3 (24.1-26.6)	19.3 (18.2-20.4)
Q5 (=most deprived)	**50.9 (49.5-52.3)**	**24.2 (23.0-25.4)**	**18.3 (17.3-19.4)**
Age 70+ years			
Q1 (=least deprived)	45.6 (43.7-47.5)	20.6 (19.1-22.2)	13.5 (12.2-14.8)
Q2	43.4 (41.7-45.1)	18.9 (17.5-20.2)	12.1 (11.0-13.2)
Q3	43.2 (41.5-44.8)	18.7 (17.4-20.0)	12.0 (10.9-13.1)
Q4	**43.0 (41.2-44.7)**	**18.5 (17.2-19.9)**	**11.9 (10.8-13.0)**
Q5 (=most deprived)	43.7 (42.1-45.4)	19.1 (17.8-20.4)	12.3 (11.2-13.4)
Low grading			
Q1 (=least deprived)	57.8 (55.9-59.6)	31.1 (29.3-32.9)	23.1 (21.5-24.7)
Q2	57.8 (56.1-59.5)	31.2 (29.5-32.9)	23.1 (21.6-24.7)
Q3	57.6 (55.7-59.5)	31.0 (29.2-32.8)	23.0 (21.4-24.6)
Q4	55.5 (53.7-57.2)	28.9 (27.2-30.5)	21.1 (19.7-22.6)
Q5 (=most deprived)	**55.3 (53.6-57.0)**	**28.8 (27.1-30.4)**	**21.1 (19.6-22.5)**
High grading			
Q1 (=least deprived)	43.1 (41.4-44.8)	17.7 (16.4-19.0)	12.4 (11.3-13.5)
Q2	42.2 (40.6-43.8)	17.1 (15.9-18.3)	11.9 (10.9-13.0)
Q3	42.2 (40.6-43.9)	17.1 (15.9-18.3)	11.9 (10.9-12.9)
Q4	42.4 (40.7-44.0)	17.2 (16.0-18.5)	12.0 (11.0-13.1)
Q5 (=most deprived)	**42.0 (40.3-43.6)**	**16.9 (15.7-18.1)**	**11.7 (10.8-12.8)**
NSCLC			

Q1 (=least deprived)	51.7 (50.3-53.0)	26.2 (25.0-27.4)	19.1 (18.1-20.1)
Q2	51.1 (49.9-52.3)	25.7 (24.6-26.8)	18.7 (17.7-19.6)
Q3	51.5 (50.3-52.7)	26.1 (25.0-27.1)	19.0 (18.0-19.9)
Q4	50.1 (48.9-51.4)	24.9 (23.8-25.9)	18.0 (17.0-18.9)
Q5 (=most deprived)	**49.9 (48.8-51.1)**	**24.7 (23.6-25.7)**	**17.8 (16.9-18.7)**
SCLC			
Q1 (=least deprived)	39.8 (36.8-42.7)	11.8 (10.0-13.8)	8.2 (6.7-9.8)
Q2	39.2 (36.4-41.9)	11.4 (9.8-13.3)	7.9 (6.5-9.4)
Q3	**37.1 (34.4-39.8)**	**10.3 (8.7-12.0)**	**7.0 (5.7-8.4)**
Q4	38.6 (35.9-41.4)	11.1 (9.5-12.9)	7.6 (6.3-9.1)
Q5 (=most deprived)	37.6 (35.0-40.1)	10.5 (9.0-12.1)	7.2 (6.0-8.5)
Period 2000-2010			
Q1 (=least deprived)	48.5 (47.1-50.0)	22.3 (21.1-23.5)	16.0 (15.0-17.0)
Q2	48.4 (47.1-49.8)	22.2 (21.1-23.3)	15.9 (15.0-16.9)
Q3	47.9 (46.6-49.2)	21.8 (20.7-22.8)	15.6 (14.7-16.5)
Q4	47.8 (46.5-49.2)	21.7 (20.6-22.8)	15.5 (14.6-16.5)
Q5 (=most deprived)	**47.6 (46.3-48.8)**	**21.5 (20.5-22.5)**	**15.4 (14.5-16.2)**
Period 2011-2015			
Q1 (=least deprived)	51.0 (49.0-53.1)	25.6 (23.8-27.5)	-
Q2	50.0 (48.1-51.9)	24.7 (23.0-26.5)	-
Q3	50.9 (48.8-52.9)	25.5 (23.6-27.3)	-
Q4	48.5 (46.5-50.4)	23.5 (21.8-25.2)	-
Q5 (=most deprived)	**47.5 (45.5-49.5)**	**22.7 (21.0-24.5)**	-
Chemotherapy			
Q1 (=least deprived)	**47.6 (45.9-49.2)**	**17.2 (15.9-18.5)**	**11.1 (10.1-12.2)**
Q2	49.0 (47.4-50.6)	18.4 (17.1-19.7)	12.0 (11.0-13.1)
Q3	49.1 (47.5-50.7)	18.4 (17.1-19.8)	12.1 (11.0-13.1)
Q4	49.0 (47.3-50.6)	18.3 (17.0-19.7)	12.0 (10.9-13.1)
Q5 (=most deprived)	48.6 (47.1-50.1)	18.0 (16.8-19.3)	11.7 (10.8-12.8)
Radiotherapy			
Q1 (=least deprived)	55.8 (53.5-58.0)	23.0 (20.9-25.2)	15.1 (13.4-17.0)
Q2	55.1 (53.1-57.0)	22.4 (20.5-24.3)	14.6 (13.0-16.3)
Q3	56.4 (54.4-58.3)	23.6 (21.7-25.6)	15.7 (14.0-17.4)
Q4	56.6 (54.6-58.5)	23.8 (21.9-25.8)	15.8 (14.1-17.6)
Q5 (=most deprived)	**54.3 (52.5-56.2)**	**21.7 (19.9-23.4)**	**14.0 (12.6-15.6)**
Surgery			
Q1 (=least deprived)	83.7 (82.1-85.1)	61.0 (58.2-63.6)	49.5 (46.4-52.5)
Q2	84.4 (82.9-85.7)	62.4 (59.8-64.8)	51.1 (48.2-53.9)
Q3	82.5 (81.0-83.9)	58.9 (56.4-61.3)	47.2 (44.4-49.9)
Q4	**81.8 (80.3-83.3)**	**57.5 (55.0-59.9)**	**45.7 (43.0-48.4)**
Q5 (=most deprived)	82.2 (80.7-83.6)	58.2 (55.8-60.6)	46.5 (43.8-49.1)
Follow-up length: 5 years			
Q1 (=least deprived)	49.9 (48.7-51.1)	24.0 (23.0-25.0)	17.7 (16.8-18.6)
Q2	48.9 (47.7-50.0)	23.1 (22.2-24.1)	16.9 (16.1-17.8)
Q3	49.1 (48.0-50.2)	23.3 (22.4-24.3)	17.1 (16.3-17.9)
Q4	48.3 (47.1-49.4)	22.6 (21.7-23.6)	16.5 (15.7-17.3)
Q5 (=most deprived)	**48.1 (47.0-49.2)**	**22.5 (21.6-23.4)**	**16.4 (15.6-17.2)**

Lowest overall survival among the quintiles is printed in bold.

[a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years) and sex (males, females), year of diagnosis, cancer subtype (NSCLC, SCLC), grading (well- or moderately differentiated, poorly or undifferentiated), stage at diagnosis (I, II, III, IV).

Table A5 Sensitivity analysis: Association between area-based socioeconomic deprivation (including Dresden city as additional category) and lung cancer survival overall in a German population and stratified by patient and tumor characteristics with full adjustment.

Subgroup (Model)	Events N (%)	Deprivation quintile Hazard ratio (95% confidence interval)*					
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)	Dresden city
All (Model 1)[a]	18,277 (79.8)	1.00 (ref.)	1.04 (0.98-1.09)	1.03 (0.98-1.09)	1.03 (0.98-1.08)	**1.06 (1.01-1.11)**	0.95 (0.90-1.00)
All (Model 2)[b]	18,277 (79.8)	1.00 (ref.)	1.02 (0.97-1.08)	1.03 (0.98-1.08)	1.03 (0.98-1.08)	**1.06 (1.01-1.11)**	0.99 (0.93-1.04)
All (Model 3)[c]	18,277 (79.8)	1.00 (ref.)	1.02 (0.96-1.07)	1.02 (0.97-1.08)	1.05 (1.00-1.10)	**1.06 (1.01-1.11)**	1.02 (0.96-1.08)
All (Model 4)[d]	18,277 (79.8)	1.00 (ref.)	1.02 (0.96-1.08)	1.00 (0.95-1.06)	1.02 (0.97-1.08)	1.02 (0.97-1.08)	0.96 (0.90-1.02)
Men	13,677 (82.0)	1.00 (ref.)	1.03 (0.97-1.10)	1.03 (0.97-1.10)	1.06 (1.00-1.12)	**1.08 (1.02-1.14)**	1.03 (0.96-1.09)
Women	4,600 (74.0)	1.00 (ref.)	0.96 (0.86-1.06)	0.97 (0.88-1.08)	1.01 (0.91-1.11)	0.99 (0.90-1.10)	0.99 (0.88-1.10)
Age 15-69 years	10,136 (77.6)	1.00 (ref.)	0.97 (0.91-1.05)	0.98 (0.91-1.05)	1.02 (0.96-1.09)	**1.07 (1.00-1.14)**	1.00 (0.92-1.08)
Age 70+ years	8,141 (82.7)	1.00 (ref.)	1.07 (0.98-1.16)	**1.10 (1.01-1.19)**	**1.09 (1.01-1.17)**	1.06 (0.99-1.14)	1.05 (0.97-1.14)
Stage I/II	3,182 (56.8)	1.00 (ref.)	1.01 (0.87-1.16)	**1.16 (1.02-1.32)**	**1.17 (1.04-1.32)**	**1.13 (1.01-1.28)**	0.90 (0.78-1.03)
Stage III	4,978 (82.3)	1.00 (ref.)	1.00 (0.90-1.13)	1.08 (0.97-1.19)	1.01 (0.92-1.12)	**1.13 (1.03-1.24)**	0.97 (0.87-1.07)
Stage IV	10,117 (89.9)	1.00 (ref.)	1.01 (0.94-1.09)	0.97 (0.90-1.05)	1.02 (0.96-1.10)	1.00 (0.94-1.07)	1.08 (1.00-1.16)
Low/intermediate grade	18,277 (79.8)	1.00 (ref.)	1.06 (0.96-1.16)	1.04 (0.95-1.13)	1.08 (1.00-1.18)	**1.09 (1.00-1.18)**	0.92 (0.84-1.01)
High grade	10,558 (83.4)	1.00 (ref.)	0.99 (0.92-1.06)	1.01 (0.94-1.09)	1.02 (0.95-1.09)	1.04 (0.97-1.11)	**1.11 (1.02-1.20)**
NSCLC	14,756 (78.0)	1.00 (ref.)	1.03 (0.97-1.10)	1.01 (0.96-1.08)	1.05 (0.99-1.11)	**1.06 (1.00-1.12)**	0.99 (0.93-1.05)
SCLC	3,521 (88.5)	1.00 (ref.)	0.95 (0.84-1.07)	1.06 (0.94-1.20)	1.04 (0.93-1.16)	1.07 (0.96-1.19)	**1.20 (1.05-1.38)**
Period 2000-2010	13,228 (89.6)	1.00 (ref.)	1.00 (0.93-1.08)	1.02 (0.97-1.09)	1.03 (0.97-1.09)	1.03 (0.98-1.09)	1.01 (0.95-1.08)
Period 2011-2015	5,049 (62.1)	1.00 (ref.)	1.04 (0.95-1.13)	0.98 (0.87-1.10)	1.09 (0.99-1.19)	**1.12 (1.03-1.23)**	1.03 (0.93-1.15)
Chemotherapy	9,759 (84.3)	1.00 (ref.)	0.98 (0.91-1.06)	0.97 (0.90-1.04)	0.96 (0.90-1.02)	0.97 (0.91-1.03)	**0.91 (0.84-0.98)**
Radiotherapy	5,733 (82.8)	1.00 (ref.)	0.97 (0.87-1.08)	0.96 (0.87-1.06)	0.97 (0.89-1.06)	1.05 (0.96-1.14)	1.06 (0.96-1.16)
Surgery	3,121 (54.3)	1.00 (ref.)	1.04 (0.90-1.19)	**1.15 (1.02-1.30)**	**1.13 (1.00-1.27)**	1.10 (0.98-1.24)	**0.80 (0.70-0.93)**
FU length: 3 months	4,385 (19.1)	1.00 (ref.)	1.04 (0.93-1.16)	1.04 (0.93-1.16)	**1.13 (1.02-1.25)**	1.10 (0.99-1.21)	1.12 (1.00-1.25)
FU length: 1 year	11,510 (50.3)	1.00 (ref.)	1.01 (0.95-1.09)	1.05 (0.98-1.12)	**1.07 (1.00-1.13)**	**1.06 (1.00-1.13)**	1.06 (0.99-1.14)
FU length: 3 years	16,452 (71.8)	1.00 (ref.)	1.02 (0.97-1.08)	1.02 (0.96-1.08)	1.04 (0.99-1.10)	1.05 (1.00-1.10)	1.04 (0.98-1.10)
FU length: 5 years	17,420 (76.1)	1.00 (ref.)	1.03 (0.97-1.09)	1.03 (0.97-1.09)	**1.06 (1.00-1.11)**	**1.06 (1.01-1.11)**	1.04 (0.98-1.10)

Abbreviations: FU, follow-up; N, number of events; n/a, not applicable; NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years), sex (males, females) and year of diagnosis; [b]Same adjustment as model 1 plus cancer subtype (NSCLC, SCLC) and grading (well- or moderately differentiated, poorly or undifferentiated); [c]Same adjustment as model 2 plus stage at diagnosis (I, II, III, IV). This model was used in all stratified analyses; [d]Same adjustment as model 3 plus registry (Dresden, Erfurt, Regensburg); *Hazard ratios with p<0.05 are printed in bold

Table A6 Sensitivity analysis: Association between area-based socioeconomic deprivation and lung cancer survival in a German population stratified by treatment with different follow-up start.

FU start/ Subgroup	Events N (%)	Deprivation quintile Hazard ratio (95% confidence interval)*[a]				
		Q1 (Least deprived)	Q2	Q3	Q4	Q5 (Most deprived)
Follow-up start: 30 days after diagnosis						
Chemotherapy	9,011 (84.3)	1.00 (ref.)	0.95 (0.89-1.02)	0.96 (0.90-1.03)	0.97 (0.91-1.04)	0.98 (0.91-1.04)
Radiotherapy	5,557 (82.9)	1.00 (ref.)	1.02 (0.93-1.12)	0.99 (0.90-1.08)	0.99 (0.91-1.09)	1.05 (0.97-1.15)
Surgery	2,944 (53.8)	1.00 (ref.)	0.93 (0.82-1.06)	1.08 (0.96-1.22)	1.12 (0.99-1.27)	1.11 (0.98-1.25)
Follow-up start: 60 days after diagnosis						
Chemotherapy	9,011 (84,7)	1.00 (ref.)	0.95 (0.89-1.02)	0.96 (0.90-1.03)	0.97 (0.91-1.04)	0.98 (0.91-1.04)
Radiotherapy	5,557 (83.2)	1.00 (ref.)	1.02 (0.93-1.12)	0.99 (0.90-1.08)	0.99 (0.91-1.09)	1.05 (0.97-1.15)
Surgery	2,944 (54.1)	1.00 (ref.)	0.93 (0.82-1.06)	1.08 (0.96-1.22)	1.12 (0.99-1.27)	1.11 (0.98-1.25)
Follow-up start: 90 days after diagnosis						
Chemotherapy	8,612 (84.7)	1.00 (ref.)	0.95 (0.89-1.02)	0.96 (0.90-1.03)	0.98 (0.91-1.05)	0.97 (0.91-1.04)
Radiotherapy	5,348 (83.2)	1.00 (ref.)	1.02 (0.93-1.11)	0.98 (0.90-1.08)	0.99 (0.90-1.09)	1.06 (0.97-1.16)
Surgery	2,856 (53.9)	1.00 (ref.)	0.93 (0.82-1.06)	1.07 (0.95-1.21)	1.10 (0.97-1.25)	1.10 (0.98-1.24)
Excluding cases with therapy start after 1 year						
Follow-up start: 30 days after diagnosis						
Chemotherapy	8,815 (84.3)	1.00 (ref.)	0.95 (0.89-1.02)	0.97 (0.90-1.03)	0.97 (0.91-1.04)	0.98 (0.92-1.04)
Radiotherapy	5,436 (83.1)	1.00 (ref.)	1.03 (0.94-1.12)	1.00 (0.91-1.09)	1.01 (0.92-1.10)	1.06 (0.97-1.16)
Surgery	2,711 (52.3)	1.00 (ref.)	0.92 (0.81-1.05)	1.06 (0.93-1.20)	1.10 (0.97-1.25)	1.09 (0.97-1.24)
Follow-up start: 60 days after diagnosis						
Chemotherapy	8,815 (84.8)	1.00 (ref.)	0.95 (0.89-1.02)	0.97 (0.90-1.03)	0.97 (0.91-1.04)	0.98 (0.91-1.04)
Radiotherapy	5,436 (83.4)	1.00 (ref.)	1.03 (0.94-1.12)	1.00 (0.91-1.09)	1.00 (0.92-1.10)	1.06 (0.97-1.16)
Surgery	2,711 (52.7)	1.00 (ref.)	0.92 (0.81-1.05)	1.06 (0.93-1.20)	1.10 (0.97-1.24)	1.09 (0.97-1.24)
Follow-up start: 90 days after diagnosis						
Chemotherapy	8,416 (84.8)	1.00 (ref.)	0.95 (0.89-1.02)	0.97 (0.90-1.04)	0.98 (0.91-1.05)	0.97 (0.91-1.04)
Radiotherapy	5,228 (83.4)	1.00 (ref.)	1.02 (0.93-1.12)	0.99 (0.90-1.09)	1.00 (0.91-1.10)	1.07 (0.98-1.17)
Surgery	2,623 (52.4)	1.00 (ref.)	0.91 (0.80-1.04)	1.04 (0.92-1.18)	1.07 (0.94-1.22)	1.09 (0.96-1.23)

Abbreviations: FU, follow-up; N, number of events; [a]Adjusted for age group (15-54 years, 55-59 years, 60-64 years, 65-69 years, 70-74 years, 75+ years), sex (males, females), year of diagnosis, cancer subtype (NSCLC, SCLC), grading (well- or moderately differentiated, poorly or undifferentiated) and stage at diagnosis (I, II, III, IV); *Hazard ratios with p<0.05 are printed in bold;

Supplementary material of the analysis of the Finish Cancer Registry

Table A7 Number of colorectal cancer patients diagnosed in Finland in 2007-2016, stratified by sex, area-based education, site, age, stage, urbanity and hospital district.

	Men, N (row %)[a]				Women, N (row %)[a]			
	Q1 (low edu.)	Q2	Q3	Q4 (high edu.)	Q1 (low edu.)	Q2	Q3	Q4 (high edu.)
Cases	4955 (32.7)	3832 (25.3)	3329 (22.0)	3045 (20.1)	4268 (30.7)	3484 (25.1)	3365 (24.2)	2781 (20.0)
Cancer site								
Colon	2835 (31.8)	2235 (25.1)	2050 (23.0)	1788 (20.1)	2883 (30.3)	2416 (25.4)	2323 (24.4)	1900 (20.0)
Rectum, rectosigmoid	2120 (33.9)	1597 (25.5)	1279 (20.5)	1257 (20.1)	1385 (31.6)	1068 (24.4)	1042 (23.8)	881 (20.1)
Age group								
25-44	78 (20.3)	94 (24.4)	116 (30.1)	97 (25.2)	89 (21.5)	103 (24.9)	103 (24.9)	119 (28.7)
45-54	272 (27.4)	242 (24.4)	237 (23.9)	241 (24.3)	285 (27.3)	261 (25.0)	257 (24.6)	240 (23.0)
55-64	1034 (31.8)	829 (25.5)	712 (21.9)	674 (20.7)	649 (27.0)	616 (25.6)	615 (25.6)	525 (21.8)
65-74	1614 (32.1)	1299 (25.8)	1106 (22.0)	1007 (20.0)	1093 (30.4)	920 (25.6)	885 (24.6)	694 (19.3)
75+	1957 (35.5)	1368 (24.8)	1158 (21.0)	1026 (18.6)	2152 (33.4)	1584 (24.6)	1505 (23.4)	1203 (18.7)
Stage at diagnosis								
Unknown	1211 (33.3)	901 (24.8)	742 (20.4)	778 (21.4)	1093 (30.9)	840 (23.7)	821 (23.2)	787 (22.2)
Local	1412 (32.9)	1124 (26.2)	944 (22.0)	818 (19.0)	1127 (30.4)	1004 (27.1)	892 (24.1)	682 (18.4)
Non-local	2332 (32.3)	1807 (25.0)	1643 (22.7)	1449 (20.0)	2048 (30.8)	1640 (24.7)	1652 (24.8)	1312 (19.7)
Urban/rural area								
Urban municipality	970 (10.0)	3123 (32.1)	2846 (29.2)	2803 (28.8)	835 (9.0)	2866 (31.1)	2918 (31.6)	2608 (28.3)
Rural municipality	2477 (89.6)	161 (5.8)	108 (3.9)	18 (0.7)	2122 (90.6)	122 (5.2)	90 (3.8)	9 (0.4)
Densely populated municipality	1508 (56.8)	548 (20.6)	375 (14.1)	224 (8.4)	1311 (56.3)	496 (21.3)	357 (15.3)	164 (7.0)
Hospital district								
Etelä-Karjala	205 (48.1)	207 (48.6)	14 (3.3)	-	207 (50.9)	191 (46.9)	9 (2.2)	-
Etelä-Pohjanmaa	379 (62.7)	74 (12.3)	-	151 (25.0)	361 (64.2)	63 (11.2)	-	138 (24.6)
Etelä-Savo	177 (50.3)	-	175 (49.7)	-	193 (52.6)	-	174 (47.4)	-
Helsinki	-	-	1355 (100.0)	-	-	-	1497 (100.0)	-
Itä-Savo	134 (100.0)	-	-	-	117 (100.0)	-	-	-
Kainuu	97 (46.6)	29 (13.9)	82 (39.4)	-	70 (39.3)	23 (12.9)	85 (47.8)	-

Kanta-Häme	173 (29.5)	391 (66.6)	23 (3.9)	-	128 (26.7)	326 (67.9)	26 (5.4)	-
Keski-Pohjanmaa	90 (44.3)	113 (55.7)	-	-	88 (44.7)	109 (55.3)	-	-
Keski-Suomi	308 (42.9)	22 (3.1)	50 (7.0)	338 (47.1)	281 (42.6)	28 (4.2)	43 (6.5)	308 (46.7)
Kymenlaakso	143 (20.9)	542 (79.1)	-	-	95 (16.3)	488 (83.7)	-	-
Lappi	125 (40.6)	57 (18.5)	-	126 (40.9)	111 (41.6)	43 (16.1)	-	113 (42.3)
Länsi-Pohja	46 (24.0)	71 (37.0)	75 (39.1)	-	30 (18.9)	63 (39.6)	66 (41.5)	-
Pirkanmaa	488 (33.0)	111 (7.5)	93 (6.3)	786 (53.2)	417 (31.1)	89 (6.6)	88 (6.6)	745 (55.6)
Pohjois-Karjala	250 (49.4)	-	36 (7.1)	220 (43.5)	183 (44.6)	-	38 (9.3)	189 (46.1)
Pohjois-Pohjanmaa	218 (27.2)	145 (18.1)	68 (8.5)	370 (46.2)	195 (25.2)	162 (20.9)	55 (7.1)	362 (46.8)
Pohjois-Savo	252 (35.8)	137 (19.5)	-	315 (44.7)	211 (33.5)	127 (20.2)	-	291 (46.3)
Päijät-Häme	311 (42.3)	424 (57.7)	-	-	246 (40.1)	368 (59.9)	-	-
Satakunta	295 (39.1)	460 (60.9)	-	-	248 (36.5)	431 (63.5)	-	-
Uusimaa	415 (18.4)	813 (36.1)	410 (18.2)	613 (27.2)	352 (17.3)	755 (37.1)	373 (18.3)	557 (27.3)
Vaasa	291 (48.2)	41 (6.8)	197 (32.6)	75 (12.4)	249 (48.4)	27 (5.3)	185 (36.0)	53 (10.3)
Varsinais-Suomi	468 (32.1)	186 (12.8)	751 (51.6)	51 (3.5)	407 (30.3)	186 (13.8)	726 (54.0)	25 (1.9)
Åland	90 (90.9)	9 (9.1)	NA (NA)	NA (NA)	79 (94.0)	5 (6.0)	NA (NA)	NA (NA)

Abbreviations: edu, education; N, number of observations; SD, standard deviation. [a]Percentages refer to distribution of area-based education by sex.

Table A8 Crude and age-standardized incidence rates for colorectal cancer patients diagnosed in Finland in 2007-2016, stratified by sex and education.

	Incidence (per 100,000)											
	Men						Women					
	CIR			ASR			CIR			ASR		
	Basic	Sec.	High	Basic	Sec.	High	Basic	Sec.	High	Basic	Sec.	High
Total	131.9	52.8	65.4	80.4	79.6	78.6	122.6	52.6	39.9	67.9	69.3	68.5
Hospital district												
Etelä-Karjala	153.7	46.4	72.4	81.1	72.6	78.6	138.0	57.1	42.7	60.9	73.6	81.2
Etelä-Pohjanmaa	146.2	49.1	70.8	74.9	71.5	81.9	131.5	57.5	42.9	66.9	77.2	72.7
Etelä-Savo	143.5	56.6	76.4	71.3	68.0	75.5	168.6	62.0	38.9	90.5	69.4	56.9
Helsinki	88.8	45.7	65.9	83.2	81.7	83.2	104.1	52.3	44.5	69.1	70.7	73.8
Itä-Savo	116.8	53.4	70.1	55.9	68.9	63.2	102.4	51.6	43.8	49.6	56.1	59.2
Kainuu	116.5	42.2	68.8	55.9	61.2	76.1	105.7	42.2	33.0	49.8	53.6	61.6
Kanta-Häme	142.2	72.0	82.6	80.3	104.5	92.1	128.5	53.4	39.3	65.8	70.1	66.1
Keski-Pohjanmaa	119.7	56.6	49.9	61.1	90.2	65.7	122.7	52.4	37.0	57.1	78.4	91.2
Keski-Suomi	145.8	53.9	60.3	78.8	88.6	76.2	140.8	53.6	36.4	75.9	74.7	68.1
Kymenlaakso	174.9	66.9	96.5	100.2	86.9	94.3	145.5	65.4	48.1	80.1	77.7	72.9
Lappi	115.2	44.8	64.3	61.0	64.0	76.4	111.9	47.7	31.2	60.6	58.6	58.2
Länsi-Pohja	145.0	49.3	69.9	69.4	64.5	76.9	114.3	44.7	50.8	60.2	55.3	73.3
Pirkanmaa	143.1	58.6	58.0	81.1	85.9	73.5	129.0	53.7	36.1	70.5	69.7	62.5
Pohjois-Karjala	140.5	51.6	60.5	75.5	66.5	68.8	112.0	48.2	36.3	58.3	57.2	60.4
Pohjois-Pohjanmaa	112.4	35.9	48.0	64.4	59.9	67.9	117.0	43.0	31.0	64.5	63.3	61.0
Pohjois-Savo	134.8	48.9	63.5	74.9	68.3	70.6	115.2	54.5	39.8	60.9	64.4	63.8
Päijät-Häme	163.7	55.1	83.1	99.8	76.1	88.3	133.7	50.3	40.2	71.0	60.3	62.2
Satakunta	145.8	62.1	71.1	80.6	86.3	75.5	133.3	50.4	47.5	69.2	58.8	79.8
Uusimaa	109.3	49.7	59.8	86.3	85.9	74.8	101.0	51.1	37.0	69.6	76.1	67.4
Vaasa	179.0	68.3	70.9	98.2	93.7	88.6	160.3	59.9	43.3	74.7	80.9	75.2
Varsinais-Suomi	142.9	56.8	70.9	85.5	81.8	81.4	129.6	53.6	44.7	67.4	71.5	71.6
Åland	121.6	72.3	106.0	89.0	100.3	101.0	112.0	72.4	47.1	65.1	115.4	75.6

Abbreviations: ASR, age-standardized incidence rate; CIR, crude incidence rate; Sec., secondary;

Acknowledgement

Mein größter Dank gilt all jenen, die mit ihrer wertvollen Unterstützung zum Gelingen dieser Arbeit beigetragen haben:

Zuerst möchte ich meinem Doktorvater, Prof. Dr. Hermann Brenner, meinen tiefsten Dank aussprechen für die hervorragende Betreuung sowie seine Unterstützung bei der Umsetzung dieser Arbeit. Ich habe von seiner langjährigen Erfahrung und seinen wertvollen Ratschlägen bei der Untersuchung aller Forschungsfragen sehr profitiert, was dazu beigetragen hat, meine Forschung zu verbessern.

Außerdem möchte ich Dr. Lina Jansen meinen besonderen Dank aussprechen, die mir während der Arbeit an dieser Dissertation mit Rat, Anregungen und lieben Worten zur Seite stand.

Ich danke der Deutschen Krebshilfe für die finanzielle Förderung meiner Dissertation sowie Dr. Werner Maier und den epidemiologischen und klinischen Krebsregistern, die mir ihre Daten für die Durchführung meiner Arbeit zur Verfügung gestellt haben.

Ich danke den Mitgliedern des Thesis-Advisory-Komitees, Prof. Dr. Ute Mons und Prof. Dr. Kayvan Bozorgmehr, für ihre Teilnahme an den jährlichen Treffen sowie den anregenden und konstruktiven Diskussionen.

Mein Dank gilt Dr. Janne Pitkäniemi und Dr. Karri Seppä, die es mir durch meinen Gastaufenthalt am Finnischen Krebsregister in Helsinki ermöglicht haben, meine Forschung aus einer anderen Perspektive zu erweitern.

Ein großes Dankeschön an alle Mitarbeiter der Abteilung Klinische Epidemiologie und Alternsforschung für die tolle Arbeitsatmosphäre und die unterhaltsamen Gespräche. In diesem Sinne möchte ich auch besonders den anderen Doktoranden für den fachlichen Austausch, ihre Ermutigung und natürlich für ihre Freundschaft danken. Insbesondere meinen Kollegen und guten Freunden Linda, Thomas und Feng, die nicht nur ein Zimmer mit mir teilten, sondern mich auch stets unterstützten und mir die Zeit in Heidelberg unvergesslich gemacht haben.

Und keine Würdigung wäre vollständig ohne ein ganz besonderes Dankeschön an meine Familie: meinen Eltern, die mich nicht nur während der Zeit des Schreibens dieser Dissertation, sondern immer bedingungslos unterstützt haben. Und natürlich an Jan, ohne dessen Unterstützung und Rückhalt ich das alles so nicht geschafft hätte.

Eidesstattliche Versicherung

1. Bei der eingereichten Dissertation zu dem Thema

   Regional variations in cancer outcome in Germany – assessing the impact of socioeconomic deprivation and cancer care

   handelt es sich um meine eigenständig erbrachte Leistung.

2. Ich habe nur die angegebenen Quellen und Hilfsmittel benutzt und mich keiner unzulässigen Hilfe Dritter bedient. Insbesondere habe ich wörtlich oder sinngemäß aus anderen Werken übernommene Inhalte als solche kenntlich gemacht.

3. Die Arbeit oder Teile davon habe ich bislang nicht an einer Hochschule des In- oder Auslands als Bestandteil einer Prüfungs- oder Qualifikationsleistung vorgelegt.

4. Die Richtigkeit der vorstehenden Erklärungen bestätige ich.

5. Die Bedeutung der eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unrichtigen oder unvollständigen eidesstattlichen Versicherung sind mir bekannt. Ich versichere an Eides statt, dass ich nach bestem Wissen die reine Wahrheit erklärt und nichts verschwiegen habe.

Ort und Datum Unterschrift