Assessing Associations of Suicide with Socioeconomic Status and Social Isolation

Dissertation
zur Erlangung des akademischen Grades
Dr. med.

an der Medizinischen Fakultät
der Universität Leipzig

eingereicht von
Anatol-Fiete Näher M.A.,
geb. am 14.08.1982 in Berlin-Steglitz

angefertigt an der
Klinik und Poliklinik für Psychiatrie und Psychotherapie
der medizinischen Fakultät der Universität Leipzig

Betreuerin:
Professorin Dr. med. Christine Rummel-Kluge

Beschluss über die Verleihung des Doktorgrades vom: 13.10.2020

Contents

Abbrevations

AIC . . . . . Akaike's Information Criterion
CASMIN . . . . . Comparative Analyzes of Social Mobility in Industrial Nations
FE (Estimator) . . . . . Fixed Effects (Estimator)
HPA (System/Axis) . . . . . Hypothalamic-Pituitary-Adrenocortical (System/Axis)
ICD . . . . . International Classification of Diseases
IMV (Model) . . . . . Integrated Motivational-Volitional Model (Model)
ISEI . . . . . International Socio-Economic-Index of Occupational Status
LSDVC (Estimator) . . . . . Corrected Least Squares Dummy Variable (Estimator)
POLS (Estimator) . . . . . Pooled Ordinary Least Squares (Estimator)
SES . . . . . Socioeconomic Status
SEM . . . . . Spatial Error Model
SI . . . . . Social Isolation
WHO . . . . . World Health Organization

Tables

1 Introduction

1.1 Suicide - A Global Health Burden

Almost one million people die by suicide every year, according to WHO estimates. By 2020, deliberate lethal acts are expected to contribute to 2% of the global burden of disease, ranking among the leading causes of death worldwide (WHO 2012). Thus, suicide represents a major challenge for health systems. Pointing out its urgency, the UN defined the reduction of suicide mortality as one of the target indicators in order to reach the sustainable development goals for 2030 (UN 2018). The situation is particularly severe in Europe, which exhibited the second highest suicide rate across all WHO global regions with 12.84 deaths per 100, 000 individuals in 2016 (WHO 2018). With regard to these numbers, taking action to avoid suicide has been acknowledged as one of the five priorities to improve European mental health by the European commission (EU 2008, 2017).

1.2 Risk Factors and Etiology of Suicide

Generally, suicidal behavior is driven by a wide range of factors that encompasses sociodemographic and cultural characteristics at the population level as well as the behavioral traits of individuals: A common etiological explanation of suicidality relies on the distinction between precipitating and predisposing determinants (Turecki & Brent 2016). According to the integrated motivational-volitional model (IMV; O'Connor 2011; O'Connor & Kirtley 2018), suicidal behavior itself is classified into suicide ideations and lethal or non lethal suicide acts. The IMV further assumes that precipitants are required for the formation of suicide ideations. Precipitants are thought of as the socioeconomic environment (Platt 2016) and genetic characteristics (Turecki 2014) of individuals as well as traumatic life events such as physical (Scott et al. 2010; Webb et al. 2012; Bolton et al. 2015) or psychological abuse (Stein et al. 2010; Liu & Miller 2014). In common, these factors are assumed to render individuals more likely to experience suicidal ideations. Predisposing factors on the other hand are supposed to exist in individual behavioral traits that favor transitions to suicidal acts, ideations being given. For instance, personality traits increasing the likelihood of suicidal acts are represented by poor problem solving and coping skills (Pollock & Williams 2004; Guerreiro et al. 2013) or impulsivity (Giegling et al. 2009; Gvion & Apter 2011).

1.3 Suicide Prevention

In order to achieve a lasting reduction in suicide numbers, systematic prevention is essential. For this reason, defining appropriate strategies has become a major concern for public health institutions. As it has been successfully demonstrated by intervention programs like the European Alliance Against Depression (Hegerl et al. 2009, 2010), a promising approach towards prevention exists in combining different measures intervening at different stages of the pathway that ultimately leads to suicide: whereas primary prevention aims at avoiding any kind of suicidal behavior beforehand by removing known precipitating factors and promoting protective measures in the general population, secondary prevention seeks to determine subpopulations with increased risks (Mann et al. 2005). Measures of tertiary prevention interfere in order to inhibit apparent suicidal behaviors in individuals turning into completed suicides. For example, such measures exist in psycho- and pharmacotherapeutical interventions (Wasserman et al. 2012).

A thorough investigation of the factors precipitating suicide is crucial in light of scarce healthcare budgets: the knowledge of these factors helps to identify populations at risk and thereby facilitates the precise definition of primary and secondary suicide prevention strategies. This is pivotal for the most efficient allocation of resources as it contributes to lessen the need for measures of tertiary prevention.

1.4 Social Disparities in Suicide

1.4.1 Socioeconomic Status

Regarding precipitating factors, socioeconomic status (SES) has been attributed to health inequalities since the very beginning of epidemiological research (Virchow 1848; Antonovsky 1967). Empirically, socioeconomic gradients have been extensively documented for physical as well as mental health (Marmot 2005) and constitute a major public health challenge, which equally affects all areas of health (Mackenbach et al. 2006, 2008). Throughout the past three decades, gaps in health inequalities have further widened in Europe despite the efforts undertaken by policy makers in most European countries (Mackenbach et al. 2018). A large body of literature emphasizes that socioeconomic disparities also account for considerable variances in suicide risks. Being unemployed, for example, has been shown to be linked to suicide as comprehensive literature reviews illustrate (Platt 1984; Platt & Hawton 2000). Existing associations remain robust even after controlling for other SES indicators as potential confounders (Lewis & Sloggett 1998). Further evi-

dence of relations between SES and suicidality consists in results of studies that employ income as a further SES indicator: Hiyoshi et al. (2018) conducted a cohort study based on Swedish register data incorporating individual level indices of income inequalities and observed significant increases in suicide rates. These results correspond with the findings of Qin et al. (2003) and Pan et al. (2013). Concerning occupational classes as yet another widely used measure of SES, the empirical evidence provided by several studies points out an inverse relationship with suicide risks (Platt 2016): in a longitudinal study based on census and death records, Mäki and Martikainen (2007) revealed suicide to occur significantly more often among manual workers as opposed to non-manual workers with higher occupational status. Comparable results were observed by Kim et al. (2006) and Milner et al. (2014). Employing measures of social classes defined by occupational skills, a systematic review by Milner et al. (2013) unveiled a decline in associated suicide risks from the lowest to the second most skilled occupations. Links of suicide and socioeconomic position were also established using education as a measure of SES: former findings of negative correlations between educational levels and risks of suicide were validated in two meta-analyses conducted by Li et al. (2011) and Lorant et al. (2005).

1.4.2 Social Isolation

A further indicator of socioeconomic health disparities which has recently received increased attention is social isolation (SI). Social relationships have earlier been suggested as a determinant affecting a broad range of health outcomes by Cassel (1976) and Cobb (1976). A literature review of subsequent prospective studies showed that SI represents a significant risk factor for elevated morbidity and mortality. These observations are further confirmed by two more recent literature reviews (Holt-Lunstad et al. 2010, 2015).

Generally, SI can be identified with regard to low social network quality. Following Lin (2001), network ties are required for the acquisition of resources mandatory for the achievement of individual life goals. Network quality means the scale to which existing ties provide these resources. Because few ties potentially supply sufficient resources, social network quality and (tie) quantity are not necessarily correlated. [1]

In the absence of a common measurement definition, present studies investigating the impact of social relationships on suicidality report effects of SI proxies such as marital status and housing situation. Agerbo et al. (2007) found a relation between increased risks of suicide and living alone

[1] For an extensive discussion of the relationship between social networks and health, see Berkman et al. (2000).

as well as being divorced after controlling for socioeconomic factors. In a record-linkage study conducted in Northern Ireland, O'Reilly et al. (2008) found that single marital status, small household sizes and SES measures affect suicide risks on individual levels. Regarding marital status, these results are verified by a meta-regression of 36 studies, which revealed aggregated higher suicide risks for non-married as compared to married persons (Kyung-Sook et al. 2018). Also, being divorced turned out to be associated with significantly higher suicide risks as opposed to being married (Stack & Scourfield 2015). SI is also proxied by recent relocations. These have detrimental effects on social network structures and are thus correlated with high levels of SI (Sluzki 1992). Correspondingly, residential mobility during adolescence is associated with increased risks of attempted and completed suicides (Qin et al. 2009). Haynie et al. (2006) validate these findings for female individuals, though they fail to replicate these findings for males. Suicide risks furthermore increase among elderly individuals with residential changes (Alexopoulos 2005). To date, there are no studies available that systematically examine the effects of relocations on suicidality at middle ages, however.

1.4.3 Health Inequalities and Health Inequities

In conclusion, the compelling evidence on socioeconomic disparities in suicidality warrants further research in order to define appropriate policies for their reduction. It needs to be considered, however, that corresponding interventions rest on normative assumptions. The notion of "health inequalities" or "disparities" is closely related to the concept of health inequity. Whereas health equality means the absence of quantitative differences in a given health outcome between individuals or populations, the term "health equity" refers such health disparities to a normative evaluation. The ethical foundation for policies against health disparities implies that health inequalities are only acceptable if they exist due to free individual health decisions (Adler et al. 2016), for instance: converging evidence indicates that chances for good health are restricted to the socioeconomic environment of individuals, which in particular impacts on life courses at very early stages (Marmot et al. 2008). Thus, health choices are not entirely free. It is consequently assumed that measures against health disparities need to be taken because "the conditions that need to be met for regarding health inequalities as fair are, in fact, extremely stringent" (Kawachi et al. 2002).

From a societal perspective, identifying gaps in health equality is also essential in terms of equally distributed growth and development. Conditions of poor health impose high burdens on

economies not only through the direct costs associated with diagnosis and therapy but a also through the indirect costs that result from income and productivity losses due to absence from work, early retirements, disability and mortality – inter alia caused by suicides (Bloom et al. 2012; Gustavsson et al. 2011; Trautmann et al. 2016). Concerning mental disorders, Trautmann et al. (2016) project the associated worldwide cumulative economic output loss to be higher than the losses caused by diabetes, chronic respiratory diseases or cancer and equal to those associated with cardiovascular diseases in 2030. Findings from research on individual-level economic outcomes of poor health further complement the evidence on health-related societal burdens. In accordance with similar findings across a large range of disease groups (Bor et al. 2017), mental health conditions reduce individual economic productivity (Lim et al. 2000; Goetzel et al. 2003; Parker et al. 2009) and cause considerably lower household and family incomes in developed countries (Sturm & Gresenz 2002; Kawakami et al. 2012). Poor mental health also severely impairs educational attainment (Kessler et al. 1995; Fergusson & Woodward 2002). The need to take action against health inequalities for ethic and economic reasons has been addressed in the WHO's Rio Political declaration on the social determinants of health (WHO 2011) and been reaffirmed in the WHO's 13th General Program of Work 2019 – 2023 (WHO 2018).

1.4.4 Causation and Selection

Apart from research results based on designs that allow the estimation of causal effects, it needs to be taken into account that existing associations of SES and suicidal behavior allow for causality in both directions. The largest part of suicides is preceded by psychiatric disorders (Chesney et al. 2014; Ferrari et al. 2014). While mental illness determines lower SES, lower SES may also lead to poor mental health conditions. This has led to the formulation of two distinct theoretical concepts: the social causation hypothesis of psychopathology posits that low SES is accompanied by high burdens of psychosocial stress, which in turn triggers mental illness and thereby increases suicide risks. The social selection hypothesis on the contrary rests on the assumption that individuals experiencing mental illness drift downwards in terms of SES and fail to escape low status positions (Dohrenwend et al. 1992; Mossakowski 2014; Patel et al. 2018). Following this line of reasoning, suicide would be associated with lower SES because the afflicted individuals lost higher SES positions due to mental illness before the suicidal event. Obviously, regarding completed suicides, selection effects other than those of such possible confounders of suicidality cannot be tested empirically.

There exists evidence from longitudinal studies supporting both, selection into low socioeconomic positions due to mental disorders as well as the social causation of psychiatric disorders and suicide. As an example in favor of the selection hypothesis, McLeod and Kaiser (2004) investigated educational outcomes in a US study and found a significantly reduced likelihood of emotional distress at early ages to significantly reduce the likelihood of completing high school or visiting a college. A further confirmation of mental illness-induced social selection is provided by Breslau et al. (2008) who assessed effects of early-onset psychiatric conditions on early school termination. Controlling for childhood adversities and SES, their study revealed significant associations of mental disorders with subsequent drop-outs prior to graduation across different kinds of schools, ranging from high school and college to university. Accounting for backward causation, the study by Mousteri et al. (2019) revealed adolescent psychiatric conditions to result in adult unemployment. This result is further supported by Chatterji et al. (2011) and Banerjee et al. (2017) who observed individuals with current psychiatric diagnoses being less likely to be actively engaged in the labor market using an instrumental variable approach in order to rule out reverse causality. Moreover, persistent reductions in adult incomes are linked to mental distress experienced during childhood and adolescence (Goodman et al. 2011; Evensen et al. 2017; Butterworth et al. 2012).

There also exists evidence on mental health outcomes that corroborates the social causation hypothesis. For example, Johnson et al. (1999) conducted a longitudinal community based survey including 736 U.S. families from 1973 to 1993. Their results revealed associations of low family education levels, parental occupational status and incomes in childhood with adult depression disorders. In another study, Power et al. (2002) analyzed data from the 1958 British birth cohort over three decades. Childhood material circumstances, education and parental social class turned out to affect degrees of depression, anxiety and psychosomatic symptoms of men and women at the age of 33. Further studies confirm these findings (Miech et al. 1999; Gilman et al. 2002; Costello et al. 2003; Wadsworth & Achenbach 2005; Stansfeld et al. 2011; McLaughlin et al. 2011; Melchior et al. 2013). Low adolescence SES is found to increase the risk of psychopathology in adulthood, too (Huurre et al. 2005; Zimmerman & Katon 2005; Walsh et al. 2012).

Regarding a possible social causation of suicide, poor mental health may act as an intermediary variable between SES and suicidal behaviour (e.g. Hudson 2005). This proposition receives support by the findings of Blakely et al. (2003). In their study assessing associations of labour force participation and socioeconomic position with suicide deaths among New Zealand census

respondents, the authors demonstrated mental illness to largely mediate increased suicide risks due to prior job losses. Corresponding to these observations, Milner et al. (2014) conducted a systematic meta-analysis of the existing literature and reported the relative suicide risks associated with unemployment to decline after controlling for mental health. Evidence regarding a social causation of suicide other than unemployment is missing. To the author's knowledge there are no studies available that assess the causal effects of SES measures as education or income on suicide risks, aside from research merely reporting associations of SES and Suicide.

Concerning correlations of SI with mental illness and suicide, the direction of causality needs to be accounted for as well. It is well known from research and clinical contexts that, due to impairments in social functioning, individuals encounter declines in quality of their personal social networks while experiencing acute or chronic mental illness (Kupferberg et al. 2016). SI is affected by mental health. Hence, associations between outcomes of mental health and SI levels are potentially caused by social selection. Since completed suicide cannot lead to selection effects, also interpretations of relations of SI with suicidality need to take account of mental illness as a confounding factor. As far as the author is informed, there are no previous studies available, however, that separate social selection from social causation outcomes by employing designs that allow the estimation of causal effects of SI on suicidal behavior.

1.4.5 Individual Life Courses

Overall, the literature on the social causation or selection of health gradients shows ambiguous results across the boundaries of various scientific disciplines. Common empirical support is found for both hypotheses, as it is confirmed by a recent meta-analysis (Kröger et al. 2015). A possible explanation for these findings arises from a life course perspective on the interactions between socioeconomic environment and health. According to this approach, disease and mortality risks at adult age are the endpoints of a lifelong process of interactions between biological traits, behavior and socioeconomic surroundings of individuals (Ben-Shlomo & Kuh 2002; Kuh et al. 2003).

A major advantage of the life course perspective is that its long-term approach towards the investigation of health disparities allows to determine the order of events in time. Because this makes it possible to identify the direction of causal effects, mechanisms of social selection can be separated from mechanisms of social causation in the formation of health inequalities. This additionally permits to assess the relative importance of selection and causation and their changes over different stages of life (Hoffmann et al. 2019). With regard to mental health outcomes, it can

be reasoned that social selection predominantly explains associations with SES during early life and adolescence while social causation links SES with psychiatric disorders at adult ages. High childhood stress levels that result from low childhood SES set up a trajectory that, in turn, impedes status attainment (Diewald et al. 2015; Shanahan 2013). As a consequence, low adult SES may in turn further affect mental health (Adler et al. 2012) and suicidality.

There exists some evidence in favor of this proposition. Long term effects of childhood SES on mental health outcomes are mediated by SES levels at adult age (Mossakowski 2008; Mckenzie et al. 2010). Further support is also provided by the works of Quesnel-Vallée and Taylor (2012). The authors estimated growth curve models in order to estimate the direct and indirect pathways linking childhood SES to adult psychopathology. Besides a mediation of early SES effects by adult education, the authors showed parental education to affect offspring educational levels. Income was found to largely alleviate the influences of adult educational levels on psychological distress. As the authors suggest, increased risks of depressive illness may therefore originate from low parental SES leading to poor offspring education and further to low incomes and job positions. These again may affect mental health outcomes in the most vulnerable individuals. The results from research on suicide rates are consistent with this. Kristensen et al. (2010) linked suicide deaths among all Norwegian male live births between 1967 and 1971 to register data and observed low educational levels at the age of 28 years to moderate the effects of parental education on suicide risks. Similar results are presented by Kosidou et al. (2014) who found effects of school performance at adolescence on suicide attempts to be attenuated by socioeconomic conditions at adult age.

1.5 Stress and Diathesis

The formation of social selection throughout the life course is explained by the fact that the cognitive impairments associated with mental illness compromise the acquisition of educational and professional qualifications (Slominski et al. 2011). However, the findings from life course research do not explain how exposure to a given socioeconomic environment translates into mental illness and suicide, even if they suggest possible pathways ultimately leading to suicidality. Rather, explaining mechanisms can be delineated from a diathesis-stress-approach, which also represents the theoretical background of the IMV model of suicidal behavior (O'Connor & Kirtley 2018). The diathesis-stress-model rests upon the assumption that suicidality and preceding mental illness is more likely to occur in predisposed individuals. Increased suicide risks are postulated to emerge

from the interactions between living conditions and individual susceptibilities (O'Connor & Nock 2014; Mann & Currier 2016). While such vulnerabilities are supposed to exist in genetically and epigenetically determined neurobiological traits, external stressors arising from socioeconomic environments are thought of as the significant triggers that affect individual diatheses such that psychiatric conditions and suicidal behavior become more likely in respective subjects.

1.5.1 Critical Life Events

A commonly accepted definition describes external stressors as environmental demands that are consensually perceived as being threatening or harmful (Cohen et al. 1983; Epel et al. 2018). Exposure to recent stressors represents a major risk factor for depression and predicts the onset and recurrence of its clinical symptoms (Kendler et al. 2000; Slavich & Irwin 2014; Cohen et al. 2019). Likewise, suicidal behavior is also more likely to appear in subjects experiencing life events accompanied by severe stress (Brodsky & Stanley 2001; Bruffaerts et al. 2010; Krysinska & Lester 2010). While this holds true for the occurrence of several critical events throughout the life course of individuals, various studies demonstrated that even single incidents lead to increased suicidality (Beautrais et al. 1997; Cleary 2000; Cougle et al. 2009; Flannery et al. 2001; Lemaire & Graham 2011). The extent to which sudden stressful events possibly trigger mental illness and suicidal acts depends on their intensity, duration, imminence of harm and possible controllability (Lazarus & Folkman 1984; Cohen et al. 2016).

1.6 Neurobiological Correlates of Suicidality

Several observations from family studies confirm the hypothesis that individual susceptibilities to suicidal behavior are determined by genetic factors (Wasserman et al. 2009). Variations in genetic polymorphisms are thought of to account for interindividual differences in resilience towards external stressors as it has been formulated in the diathesis-stress-model (Wasserman et al. 2009). Well established evidence identifies the gene loci controlling the expression of the hypothalamic-pituitary-adrenocortical (HPA) system as pivotal stress-related factors contributing to suicidal behavior (GR, NR3C1, SKA2, FKBP5, CRHR; Mann & Currier 2016; Melhem et al. 2017). The HPA axis integrates information from the central nervous system into peripheral endocrinological responses. It represents the main biological mechanism that maintains the adaptation of the human allostatic system to stressors resulting from adverse life events or socioeconomic environments

(Danese & McEwen 2012).[2] As previous evidence shows, environmental stress potentially induces neuroplasticity alterations in the limbic (Watanabe et al. 1992; Magariños et al. 1996; Vyas et al. 2002; Mitra et al. 2005; Vyas et al. 2006; Mirescu & Gould 2006) and medial prefrontal (Wellman 2001; Radley et al. 2004, 2006, 2008) brain areas, leading to altered HPA activity levels (Surget et al. 2011; Anacker & Pariante 2012; Turecki et al. 2012). Associations of HPA hypo- and hyperactivity and increased risks of completed suicide have been observed in prospective studies on individuals suffering from mental illness (Mann et al. 2006; Mann & Currier 2007; Jokinen et al. 2010). The precise conditions under which specific HPA activity levels lead to suicidal behavior remain unclear, however.

1.6.1 Neurobiological Correlates of SES and SI

With regard to the effects of SES and SI on mental health and elevated suicide risks, it is argued that these are accompanied by psychosocial stress. Especially the stressors that come along with early life adversity are thought to cause lasting neuroplasticity alterations. These, in turn, render individuals with a history of exposure more vulnerable to environmental stressors in adult life (McEwen 2012). Research findings support these propositions: generally, adult humans who experienced childhood trauma show HPA axis perturbations (Heim et al. 2008). Concerning socioeconomic adversities, greater hair cortisol levels have been observed as a measure of HPA activity in adolescents with low childhood SES, for example (Vliegenthart et al. 2016). Also greater HPA reactivity to external stressors was found to be related to socioeconomic disadvantages (Hackman et al. 2012). There is evidence, however, that stress emerging from low SES is also associated with lower HPA activity (Badanes et al. 2011), too. Thus, although specific mechanisms are not known, low SES is linked to some kind of altered HPA regulation (Ursache & Noble 2016). Also current SES at adult age is related to HPA axis activity as observations from cross-sectional research indicate (Cohen et al. 2006; Kumari et al. 2010). The causal direction of these effects can not be identified given the design of these studies, though.

Comparable observations have been made regarding the repercussions of SI on the HPA system. Koss et al. (2014, 2016) compared adopted children with a prior history of SI in orphanages to same-aged non-adopted peers and found signs of blunted HPA reactivity two years after adoption. Alterations in HPA persist even 20 years after severe social deprivation (Kumsta et al. 2017) and are related to mood and anxiety disorders (Sonuga-Barke et al. 2017). While these results suggest

[2] There exist other neurobiological correlates of suicidal behaviour (Mann & Currier 2016). These are not primarily stress-related, though.

an early programming of the HPA axis rendering individuals more vulnerable to external stressors in adult life, evidence of how concurrent SI levels affect HPA activity in humans is scarce. Findings in rodents suggest that SI directly increases basal HPA axis activity (Weiss et al. 2004; Pisu et al. 2016).

1.7 SES, SI and Social Support

With regard to elevated risks of death by suicide, there exists widespread support in the empirical and theoretical literature that social support acts as a protective factor (Kleiman & Liu 2013). According to a commonly accepted definition, social support is characterized by the provision of informational (i.e., giving advice to solve problems), instrumental (i.e., behavioral or material assistance in solving problems) as well as emotional (i.e., sympathy and understanding) resources (House 1985). Social support decreases the lifetime likelihood of suicide attempts (Kleiman & Liu 2013). As two further studies indicate, social support increases the resiliency against suicide particularly in the presence of stressful life events (Meadows et al. 2005; Yang & Clum 1994).

While experiencing adversity, a sufficient quality of the afflicted individuals' networks is crucial for receiving supportive measures. Low social network quality interferes with the provision of social support. Hence, socially isolated individuals possibly suffer from more pronounced effects of distress resulting from low SES.

1.8 Aims of the Thesis

As shown above, it is essential to further investigate the interactions of individual genetic predispositions with socioeconomic environments over time in order to fully understand the etiology of suicidal behavior. For the definition of prevention strategies however, associations of contemporary SES and SI suffice to identify populations at risk. Because evidence is lacking in Germany, the aim of the present study is to find intervention points based on potential relations of socioeconomic characteristics with suicide. It follows from sections 1.4, 1.5 and 1.6 that acute stress emanating from low SES and SI is possibly linked to increased suicide risks in individuals that are predisposed due to genetic traits and life course adversities. Since German privacy policies do not allow to test the effects of SES and SI on individual level suicide risks, the following hypotheses were tested with regard to district level outcomes:

Hypothesis I: Lower individual SES-levels are correlated with higher district suicide

rates.

Hypothesis II: Higher individual SI-levels are associated with higher district suicide rates.

It further follows from section 1.7 that predisposed individuals experiencing SI conceivably show more distinct reactions to stress originating from low current SES because SI impairs the provision of social support, which acts as a protective factor against suicidality. Suicide risks in these individuals may be increased due to interactions of SI with SES. Hence, also the following hypothesis was tested:

Hypothesis III: Lower levels of SES in individuals with higher levels of SI are linked to higher district suicide rates.

1.9 Methods

The hypotheses above were tested by utilizing the official German death record edited by the Federal Statistical Office (DESTATIS). The dataset lists all yearly German deaths by cause as coded by the ICD system (WHO 1976, 1992). Corresponding to ICD 9 categories E950 - E959 for 1997 and ICD 10 codes X60 - X84 from 1998 to 2010, all German suicide cases between 1997 and 1998 were used in order to calculate yearly age- and gender adjusted suicide rates for $N = 390$ German administrative districts. In a second step of the analysis, the data were merged with $T = 14$ annual cross-sections of the official German Microcensus resulting in a longitudinal dataset with $N \times T = 5460$ district observations. The Microcensus data, as edited by the federal statistical office (DESTATIS), are collected by means of the largest German household survey and include a large selection of individual-level socioeconomic indicators. These indicators were employed to construct internationally comparable measures of two distinct SES dimensions: Educational attainment was operationalized by the "CASMIN"-scoring approach developed by König et al. (1988). Occupational status was captured utilizing the "International Socio-Economic-Index of Occupational Status (ISEI)" (Ganzeboom & Treiman 1996). Because they are not represented by the ISEI index, indicators of minor employment and unemployment were included in the analyses. Other crucial SES components were taken account of by utilizing measures of household income, received public transfers and dependency on social benefits due to unemployment. In compliance with the proxies applied in current research, SI was captured by three Microcensus

variables recording living in a one-person-household, single marital status and a possible relocation throughout the year before the survey was conducted.

Federal regulations of data protection only permit district level analyses of suicide rates in Germany. SES and SI measures are available as individual level data, however. Thus, a statistical model was chosen that allows for the analysis of district level outcomes while it correctly specifies the functional form of effects by exploiting the additional information contained in the individual level explaining variables (Prentice & Sheppard 1995). The applied method further ensures that differences in district base line suicide rates in time and between districts as well as correlations of effects among neighboring districts do not distort the estimation results. The present study investigates associations of SES and SI with changes of suicide rates within given districts over time.

2 Original Publication

frontiers in Psychiatry

ORIGINAL RESEARCH
published: 14 January 2020
doi: 10.3389/fpsyt.2019.00898

Associations of Suicide Rates With Socioeconomic Status and Social Isolation: Findings From Longitudinal Register and Census Data

Anatol-Fiete Näher[1], Christine Rummel-Kluge[2]*† and Ulrich Hegerl[3]*†*

[1] Department of Pneumology, Helios Klinikum Emil von Behring, Berlin, Germany, [2] Department of Psychiatry and Psychotherapy, University of Leipzig, Leipzig, Germany, [3] Department of Psychiatry, Psychosomatics and Psychotherapy, Goethe Universität Frankfurt am Main, Frankfurt am Main, Germany

OPEN ACCESS

Edited by:
Michael P. Hengartner, Zurich University of Applied Sciences, Switzerland

Reviewed by:
Martin Plöderl, Christian Doppler Clinic, Austria
Melissa K. Raven, University of Adelaide, Australia

***Correspondence:**
Anatol-Fiete Näher
fiete.naeher@web.de
Christine Rummel-Kluge
christine.rummel-kluge@medizin.uni-leipzig.de
Ulrich Hegerl
ulrich.hegerl@kgu.de

†These authors share last authorship

Specialty section:
This article was submitted to Public Mental Health, a section of the journal Frontiers in Psychiatry

Received: *27 October 2018*
Accepted: *13 November 2019*
Published: *14 January 2020*

Citation:
Näher A-F, Rummel-Kluge C and Hegerl U (2020) Associations of Suicide Rates With Socioeconomic Status and Social Isolation: Findings From Longitudinal Register and Census Data. Front. Psychiatry 10:898. doi: 10.3389/fpsyt.2019.00898

Suicide represents a major challenge to public mental health. In order to provide empirical evidence for prevention strategies, we hypothesized current levels of low socioeconomic status (SES) and high social isolation (SI) to be linked to increased suicide rates in N = 390 administrative districts since SES and SI are associated with mental illness. Effects of SES on suicide rates were further expected to be especially pronounced in districts with individuals showing high SI levels as SI reduces the reception of social support and moderates the impact of low SES on poor mental health. We linked German Microcensus data to register data on all 149,033 German suicides between 1997 and 2010 and estimated Prentice and Sheppard's model for aggregate data to test the hypotheses, accounting for spatial effect correlations. The findings reveal increases in district suicide rates by 1.20% ($p < 0.035$) for 1% increases of district unemployment, suicide rate decreases of –0.39% ($p < 0.028$) for 1% increases in incomes, increases of 1.65% ($p < 0.033$) in suicides for 1% increases in one-person-households and increases in suicide rates of 0.54% ($p < 0.036$) for 1% decreases in single persons' incomes as well as suicide rate increases of 3.52% ($p < 0.000$) for 1% increases in CASMIN scores of individuals who moved throughout the year preceding suicide. The results represent appropriate starting points for the development of suicide prevention strategies. For the definition of more precise measures, future work should focus on the causal mechanisms resulting in suicidality incorporating individual level data.

Keywords: suicide, public mental health, social determinants, prevention, socioeconomic status, social isolation

INTRODUCTION

Suicide constitutes a substantial public health problem: In Europe, the local age-adjusted numbers amounted to 12.84 deaths per 100,000 individuals in 2016, according to WHO data (1). This constitutes the second highest suicide rate across all WHO global regions. In order to improve the situation, suicide prevention has been given highest priority on the agenda of the European

Abbreviations: CASMIN, Comparative Analyzes of Social Mobility in Industrial Nations; FE, Fixed Effects (Model); ICD, International Classification of Diseases; ISEI, International Socio-Economic-Index of Occupational Status; LSDVC, Corrected Least Squares Dummy Variable (Model); RE, Random Effects (Model); SEM, Spatial Error Model; SES, Socioeconomic Status; SI, Social Isolation; WHO, World Health Organization.

Comission (2). In addition to this, the reduction of suicide mortality has been defined as one of the target 3.4 indicators of the United Nations' sustainable development goals for 2030 (3).

With regard to prevention, it is of particular significance that sociodemographic characteristics mediate suicide risks: A systematic review of population level studies revealed associations of poverty and suicide rates (4). According to recent studies (5, 6) increases in suicide rates are linked to rising unemployment rates. Moreover, there exists evidence for an inverse relationship between social cohesion and suicide (7–9). Adding to these findings, the aim of this study is to provide empirical evidence on potential associations of individual level indicators of socioeconomic status (SES) and social isolation (SI) with district suicide rates. While suicide itself is a complex phenomenon determined by genetic, cultural and behavioral factors (10, 11), such associations help to identify populations at risk.

Concerning suicide risks linked to SES, a meta-analysis by Li et al. (12) found the highest relative and population attributable risks of committing suicide for males in low ranked occupational classes and for persons with low educational achievement. Among women, relative risk ratios and population attributable risks were highest for unemployed individuals and individuals with low education. Regarding relations of education and suicide, suicides were also 2.12 times more often observed in the lowest educational group as compared to individuals with the highest educational levels across 35 countries in a study combining census and mortality register data (13). Unemployment turned out to be associated with suicide in a more recent meta-analysis (14). Relative risks of these associations were reduced after controlling for prior mental health. Financial strain, as captured by a family income to poverty threshold ratio has been found to be positively related to suicide attempts and ideations in a household survey among U.S. adults (15). As further crucial measures of SES, income-based indicators of individual level inequalities were positively related to suicide risks among both genders in a longitudinal study incorporating official Swedish mortality data (16).

In contrast to these results, several studies yielded less conclusive findings. While the most recent meta-analysis revealed positive associations of suicide with low education and unemployment, the authors regard these as not clinically significant due to small effect sizes (17). Overall, the study concluded that the results warrant further research on the effects of demographics on suicidal behavior. Among Malaysian in-patients, low social class predicted transitions from suicide ideations to attempt whereas unemployment and low educational levels did not confer any significant increases in suicide attempts (18). In addition, contradictory results were reported by Lukaschek et al. (19) who failed to find a significant effect of unemployment on suicides among in-patients in six German psychiatric hospitals. Regarding in-patient samples, it is important to note that these are not necessarily representative of all individuals that die by suicide. The findings by Chan et al. (18) and Lukaschek et al. (19) might possibly not apply to suicide in general.

Low SES does not increase suicide risks per se. On the one hand, there exist links of SES and psychopathology (20–23). On the other, quantitative meta-studies reveal associations of mental disorders and suicide (24, 25), avoiding the methodological problems of psychological autopsy (26). These findings suggest mental-ill health as a possible mechanism that links low SES levels to increases in suicide risks, allowing for causality in two directions. While poor mental health may be triggered by low SES, low SES may also represent the consequence of psychopathology. Several longitudinal studies investigating both explanatory approaches suggest an interaction of mental health and SES over the life course of individuals (27, 28).

Exploring potential mechanisms that explain SES effects on suicide does not lie within the scope of this study. In order to inform public health policies, we tested the hypothesis that lower levels of contemporary SES are correlated with higher suicide rates (Hypothesis I).

Our second hypothesis relates suicides to social isolation (SI). We define SI as a lack of social network quality. In this context, social network quality itself is understood as the extent to which existing ties provide the resources an organism can draw on in order to achieve its life goals (29). SI possibly acts as a root cause for feelings of thwarted belongingness. In combination with perceived burdensomeness, thwarted belongingness is seen as critical to the development of suicide ideation in Joiner's (30) psychological model of suicide. This, in turn, leads to increased suicide risks in individuals. In accordance with the theory, the empirical evidence on links of SI with increased suicide risks is well established. Proxying for SI in a study incorporating 21,169 suicides, a Danish study revealed associations of single marital status and suicide (31). These results have been confirmed in Sweden (32), the U.S. (33), Great Britain (34), Finland (35), Austria, Belgium, Denmark, Norway and Switzerland (36) and Canada (37). Likewise, Agerbo et al. (38) found a relation between increased risks of suicide and living alone as well as being divorced. Utilizing relocations as SI proxies, several studies found these to be associated with completed and attempted suicides in adolescents (39, 40) and elderly people (41, 42).

There exists a solid body of evidence on associations between SI and mental health outcomes (43–45). Again, this suggests psychopathology as a potential pathway through which SI affects suicidality. It is important to note, however, that individuals suffering from mental illness exhibit impairments in social functioning, which leads to a disruption of personal networks (46). For this reason, not only does SI possibly affect mental health but mental health also impacts on SI levels. As is the case with SES and mental health, associations between SI and mental health outcomes do not determine the direction of causality. While this needs to be addressed with additional studies allowing for causal conclusions, we tested the second hypothesis that higher levels of SI are associated with higher suicide rates (Hypothesis II).

Social support represents a substantial social network resource for individuals in order to cope with stressful life events (47, 48) and has been shown to moderate the impact of environmental conditions on symptoms of poor mental health (49–52). Effects of low SES should thus be aggravated in socially isolated individuals. Hence, we also evaluated if interactions between lower levels of SES and higher levels of SI are linked with higher suicide rates (Hypothesis III).

DATA AND METHODS

Data

For the observation period 1997 to 2010, data on suicides were obtained from the German death record edited by the federal statistical office (DESTATIS). The dataset lists all yearly German deaths by cause as coded by the ICD system (53, 54). With regard to these data, it is relevant that German data protection regulations do not permit individual level analyses. Hence, suicide deaths were examined as aggregated rates at the level of administrative districts. It needs to be considered in this respect that, after German reunification, extensive administrative reforms including new territorial definitions of district populations were implemented in Eastern Germany. Reformed areas were therefore grouped to greater regions such that they resembled the territorial status of the observation period's last year, yielding a total of $N = 390$ districts. Non-reform-associated differences in district specific suicide rates are hereby properly identified.

In order to gain information on the socioeconomic conditions of district populations, the numerical identifiers of districts included in the record data were utilized to merge this dataset with the data provided by the German Microcensus. Based on a random household sample, the Microcensus is the official survey on living conditions in Germany. Selected respondents are legally bound to answer items on education, labor force participation, income, family and housing situation. As it can be inferred from **Table 1**, the survey's population sample size is large enough to permit district level analyses: In all observation years but 2005, it corresponds to at least 0.74% of the population sizes in 95% of the districts. A drawback of the Microcensus is, however, that one quarter of the observation units is replaced every year. Periods longer than four years are thus not covered by panel data. In order to examine suicide deaths over a longer time frame, the employed dataset was constructed from annually repeated cross sections over the course of $T = 14$ years, i.e. $N \times T = 5{,}460$ district observations.

TABLE 1 | Summary of microcensus sample sizes per district by year.

Year	Mean	Min.	Max.	5th Perc. of % Dis. Pop.
1997	4,694	305	31,233	0.78
1998	4,640	315	30,381	0.77
1999	4,568	325	29,720	0.76
2000	4,480	322	29,034	0.74
2001	4,473	343	28,732	0.74
2002	4,420	347	28,604	0.75
2003	4,429	328	28,580	0.75
2004	4,403	321	28,491	0.74
2005	4,295	292	27,795	0.59
2006	4,337	332	28,130	0.74
2007	4,207	318	27,034	0.74
2008	4,243	323	27,298	0.75
2009	4,285	320	27,675	0.77
2010	4,256	297	27,369	0.76

Min., Minimum; Max., Maximum; 5th Perc. of % Dis. Pop.: 5th Percentile of Percentage of District Population.
Source: German Microcensus & Area Population Numbers of Germany, 1997 to 2010 - ed.by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

Measures and Descriptive Statistics

We define suicide as coded by the ICD 9 categories E950–E959 for 1997 and as the lethal consequence of intentional self-harm corresponding to the ICD 10 codes X60–X84 for the years from 1998 onwards, respectively (53, 54). All 149,033 cases of suicide death according to this definition were extracted from the death record to calculate district specific suicide rates. The different coding categories introduced with the 10_{th} ICD revision in 1998 may be associated with structural breaks in reported suicide numbers and hence lead to biased estimates of suicide rates. To detect any of these breaks, yearly changes in suicide numbers per district were regressed on a dummy variable indicating the year of the ICD change controlling for district specific time trends and time fixed effects. As no significant results were found ICD 9 and ICD 10 codings of suicide are regarded as equivalent measures.

Because population structures vary over time and region, suicide rates were age- and gender-adjusted based on the 2013 European standard population to ensure the comparability across all districts. The gender specific distribution of district suicide rates over time can be inferred from **Table 2**. An illustration of the spatial distribution of the observation period means of the adjusted district suicide rates is provided by **Figure 1**.

Furthermore, as can be seen from **Figure 2**, the yearly means of the adjusted district suicide rates in Germany declined between the years from 1997 to 2010. Potential reasons for this consist in better help seeking behaviors and treatments of patients suffering from mental illness, better training of physicians to recognize suicidal behavior and the set up of intervention programs at community levels (55). In order to permit the identification of changes in suicide rates associated with SES and SI, this general linear downward trend in the data was accounted for by including a variable indicating the observation year in the models.

SES was operationalized employing measures for educational achievements, occupational status and log income. Educational achievements were quantified according to the scheme provided by the "Comparative Analyses of Social Mobility in Industrial Nations (CASMIN)" (56). The CASMIN scheme constitutes an internationally comparable measure that distinguishes hierarchical educational classes constructed from combinations of school and vocational degrees. The classes reach from 1*a* (inadequately completed general education) to 3*b* (higher tertiary education) and represent the boundaries of the respective country's educational system on the one hand and differentiate between required educational levels for certain labor market positions on the other (57).

The "International Socio-Economic-Index of Occupational Status (ISEI)" (58) was applied for the measurement of occupational status. This index relies on a continuous scoring system with values ranging from 16 (low Status) to 85 (high status). For unemployed individuals, scores of the last occupation were utilized. Beyond that, unemployment and, as it is not included in the ISEI scheme, minor employment were recorded in own variables and included in the analysis.

TABLE 2 | Summary of age and gender standardized district suicide rates by year and gender.

	Females				Males			
Year	**Mean**	**S.D.**	**Min.**	**Max.**	**Mean**	**S.D.**	**Min.**	**Max.**
1997	4.04	1.90	0.44	12.19	12.95	4.97	2.88	31.07
1998	3.65	1.75	0.54	11.95	12.49	4.42	3.07	31.52
1999	3.69	1.97	0.54	21.46	11.72	4.35	1.66	32.18
2000	3.61	1.80	0.29	11.63	11.69	4.20	2.50	28.06
2001	3.49	1.75	0.55	11.53	11.73	4.42	3.06	26.04
2002	3.47	1.70	0.56	10.87	11.50	4.48	2.87	37.37
2003	3.41	1.66	0.29	13.07	11.50	4.21	1.82	30.71
2004	3.25	1.91	0.00	17.61	10.71	3.77	0.00	28.58
2005	3.25	1.79	0.00	11.71	10.36	4.22	0.00	28.59
2006	2.99	1.71	0.30	11.25	10.04	3.83	2.44	33.44
2007	2.74	1.41	0.35	8.92	9.46	3.71	2.35	25.13
2008	2.97	1.70	0.36	11.96	9.54	3.93	1.43	34.26
2009	2.81	1.67	0.35	14.07	9.67	3.60	1.31	27.48
2010	3.00	1.70	0.42	13.13	9.95	3.56	2.74	29.47

Min., Minimum; Max., Maximum; S.D., Standard Deviation.

Source: German Death Record, 1997 to 2010 - ed. by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

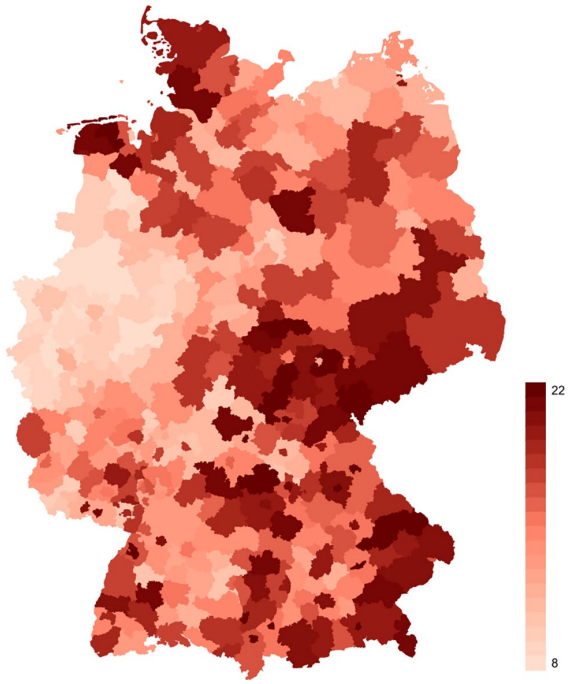

FIGURE 1 | Observation period means of age- and gender-adjusted district suicide rates in Germany. The legend on the right hand side provides color codes for suicide rate values ranging from 8 (minimum) to 22 (maximum) per 100,000 inhabitants. *Source:* German Death Record, Area Population Numbers of Germany, 1997 to 2010, and 2013 European Standard Population - ed. by the German Federal Statistical Office (DESTATIS). Stata 15.0 was used to perform own calculations and create this figure.

As another significant component of SES, we calculated the log of the equivalent household income from the income variables provided by the Microcensus. The highest psychosocial distress should result from the lowest SES conditions. In order to proxy especially for these situations, two variables indicating the receipt of social benefits due to unemployment ("ALG I/II" in Germany) and the number of received public transfers were added to the models, too.

Similar to previous studies, SI was proxied with two variables on single marital status and living in a one-person-household and a dummy variable recording a possible relocation throughout the year before the survey was conducted ("Moved last Year"). Being divorced or widowed was considered as having a single status in this context.

Age categories as provided with the European standard population were employed for the standardization of suicide rates. In order to control for exponentially increasing suicide risks with age in Germany (59) and continuous age effects, we therefore added continuous measures of age and age squared from the register dataset as controls. **Table 3** summarizes all independent variables over time.

Finally, values of the ISEI, CASMIN and log income variables were inverted and mean-centered for the calculation of the proposed $SES \times SI$ interactions.

Methods

Combining individual and district level data for the estimation of SES and SI effects on suicide rates represents a source of ecological bias. The problem arises in aggregate data analysis if summary measures are employed to calculate effects on marginal outcomes. Distributions of summaries do not determine individual distributions. Because joint individual distributions have to be specified in order to identify effect parameters, however, estimates depending solely on aggregate data are potentially biased. A first related statistical problem is that, without further assumptions, applying summary measures does not identify the functional form of effects on the individual level. To see this, let:

$$E(y_{idt}) = f(\pi_d + \beta X_{idt}), \quad (1)$$

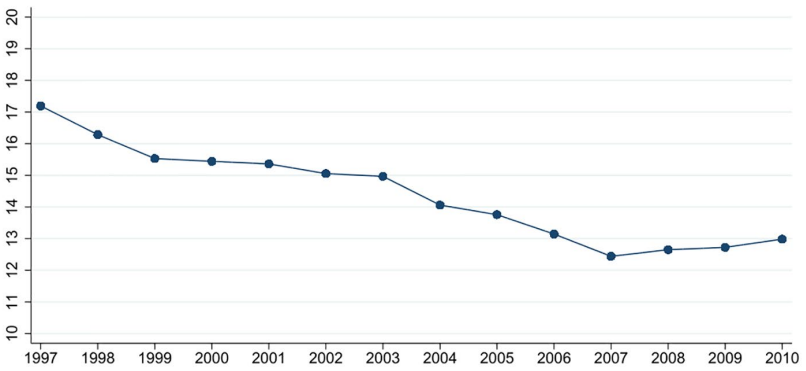

FIGURE 2 | Yearly means of age- and gender-adjusted district suicide rates in Germany. Suicides per 100,000 inhabitants shown on the y-axis, observation years shown on the x-axis. *Source:* German Death Record, 1997 to 2010 - ed. by the German Federal Statistical Office (DESTATIS), STATA 15.0 was used to create this figure.

where $f(\cdot)$ denotes a link function. y_{idt} is a binary indicator variable, with $y_{idt} = 1$ if individual $i = 1,2,\ldots,n_{dt}$ commits suicide in district $d = 1,2,\ldots,N$ at year $t = 1,2,\ldots,T$ and $y_{idt} = 0$ otherwise. X_{idt} is a row vector including the controls, the variables on SES and SI and, in order to test Hypothesis III, *SES* x *SI* interaction terms. β is a column vector with the respective parameters of interest. Further, π_d represents the district baseline probability of suicides, for $X_{idt} = 0$. Given that data on suicides is only available as district specific rates, $\bar{y}_{dt} = n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} y_{idt}$, effects of SES and SI can be estimated by the ecological model

$$E(\bar{y}_{dt}) = f(\pi_d + \beta \bar{X}_{dt}) \tag{2}$$

with $\bar{X}_{dt} = n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} X_{idt}$. As it can be seen from equations (1) and (2) the functional form of individual level effects is only correctly specified if $f(\cdot)$ is assumed to be linear and completely additive in all of its arguments. It follows in any other case that $n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} f(\pi_d + \beta X_{idt}) \neq f\left(\pi_d + \beta \bar{X}_{dt}\right)$. With regard to this, we therefore apply the aggregate data method firstly introduced by Prentice and Sheppard (60). Accordingly, the following equation is being estimated, normalizing the district specific standardized suicide rate r_{dt} by taking its log:

$$ln(r_{dt}) = n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} f(\pi_d + \beta X_{idt}) + \nu_t + \kappa_{dt}, \tag{3}$$

$$\kappa_{dt} = \rho W \tau_{dt} + \varepsilon_{dt},$$

with an identity link $f(\cdot)$ and a variance fraction ρ. The spatial contiguity matrix W accounts for a spatial correlation of error components τ_{dt} among neighboring districts due to omitted district level variables. Spatial correlation effects may result in biased estimates of suicide rates, e.g. if individuals commute between districts that differ in one or more of such unobserved traits. Further, ε_{dt}, $E(\varepsilon_{dt} \mid X_{idt}, \pi_d, \nu_t) = 0$, denotes an idiosyncratic error that is strictly exogenous. As long as this assumption holds, it is also assumed that ε_{dt} has a constant variance across time, σ_e^2 i.e. no heteroskedasticity, and that the errors are not serially correlated, $E(\varepsilon_{dt}\, \varepsilon_{dt-s}) = 0$, for all $t \neq t\text{-}s$. A last assumption that is being made is that there is no multicollinearity in the data.

The model specification as defined in (3) also considers two further potential estimation biases: First, another difficulty in assessing suicide rates with combined aggregate and individual data is that marginal distributions may designate district properties only. In this case, observed effects do not reflect any individual characteristics but rather shifts in suicide rates that depend solely on district assignment. This possibility is avoided though if we assume the district specific suicide rates to be independent of each other because this rules out any unobserved time-constant district heterogeneity. Hence, the baseline probability π_d is defined as a district fixed effect in (3). A second problem has its roots in the time dimension of the data.

TABLE 3 | Independent variables.

Variable	Mean	S.D.	N
ISEI	42.60	15.73	4,598,937
CASMIN	3.40	2.16	7,873,911
No. Public Transfers	0.24	0.51	9,923,291
Age	53.93	4.07	7,324,663
	Median	**I.Q.R.**	**N**
Income (household equiv.)	1230.77	1043.71	9,239,242
	%	**S.D. (in %)**	**N**
Minor employment	4.00	19.50	7,646,280
Unemployment	4.96	21.71	9,941,490
ALG I/II	4.64	21.03	9,941,494
Moved last year	6.92	25.39	6,438,498
Single	51.88	49.96	9,941,494
One-person-household	17.54	38.03	9,836,123
Gender (male)	73.44	8.78	7,324,663

S.D., Standard Deviation; I.Q.R., Interquartile Range
Source: German Microcensus & Death Record, 12997 to 2010 – ed. by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

Suicide rates may change because of events that commonly affect all individuals across all districts at a certain time *t*. These events, i.e. exogenous shocks, represent a source of unobserved district-constant heterogeneity, which causes an additional estimation bias. This bias is accounted for by including a time fixed effect ν_t in (3). This prevents any event at *t* distorting the estimates of suicide risks in the same period.

Generally, the linear specification of $f(\cdot)$ greatly simplifies the procedure and allows us to employ the quasi-maximum-likelihood fixed effects estimator for longitudinal spatial error models (SEM) developed by Lee and Yu (61) in order to fit (3).

The models' residuals were tested for autocorrelation and no autocorrelation was detected by Wooldridge's autocorrelation test (62), $F(1,389) = 1.923$ ($p > F = 0.166$). Moreover, Wald tests were conducted for stepwise model selection based on a basic fixed effect (FE) estimation of (3).

Rather than defining fixed effects, an alternate specification rests on the assumption of π_d as a random effect with $E(\pi_d \mid X_{idt}, \nu_t) = 0$. Consequently, a random effects estimator (RE) is then applied to (3). In order to compare both estimation strategies a Hausman test (63) was conducted. The results indicate that the fixed effects model is to be preferred over the random effects model, $\chi^2 = 365.28$ ($p > \chi^2 = 0.000$). For a further specification test, it was also taken into account that current suicide rates may be influenced by accumulated effects of past levels of SES and SI. We estimated a corrected least squares dummy variable model (LSDVC) (64, 65) including Koyck lags (66) of all independent variables in order to assess long run SES and SI effects on suicide rates. The model yields a mean time of only 1.2 months after which suicide rates are affected by changes in SES and SI levels. Given this high adjustment rate of the model, past SES and SI levels barely contribute to current suicide rates. See the **Supplementary Material** for the results of the additional analyses.

Limitations

The specification of our model takes account of the functional form of SES and SI effects on the individual level and rules out the estimation of any effects that depend entirely on district assignment. It does not address a further problem associated with ecological data analysis, however. Because of the information on joint distributions lost due to the aggregation of suicides in district rates, effects of district SES and SI compositions cannot be differentiated from individual level SES and SI effects. The estimated coefficients rather represent a blend of individual level and district composition effects (67). Thus, individual level effects are only identified under the untestable assumption that there exist no compositional effects. This assumption is not being made in this study. Since they potentially include individual level effects, significant results are rather regarded as indications for further research. As an additional problem, this also implies that the equations do not identify true treatment effects. Hence, our FE specifications do not reveal causal effects even though they rule out unobserved heterogeneity.

Furthermore, SI should be measured by indicators of social network quality. Such indicators are not available in the data. One-person-households and single marital status were therefore used as proxies for SI based on the assumption that both variables are associated with a comparatively lower social integration. It should be acknowledged, however, that one-person-households and single status are related to each other and, for this reason, might be correlated as well.

RESULTS

Table 4 shows the results from the SEM estimation. As can be seen, district suicide rates decrease by −0.39% ($p < 0.028$) with every percentage point increase in incomes, assuming mean sizes of district proportions of singles, individuals living in one-person-households and persons who moved during the year before suicide. Further, an increase in district unemployment proportions by 1% leads to an 1.20% increase ($p < 0.035$) in district suicide rates. Contradicting these results however, it is observed that, given mean district shares of singles, relocated persons and one-person-households again, a 1% increase in CASMIN scores results in an increase of suicide rates by 0.98% ($p < 0.021$).

TABLE 4 | SEM longitudinal regressions of district suicide rates on SES and SI.

	Spatial Error Model In District Suicide Rate	
	%–Change (95% – CI)	**p - value**
SES		
ISEI	0.1 (–0.93, 1.14)	(1.000)
CASMIN	**0.98 (0.09, 1.88)**	**(0.021)**
Income	**–0.39 (–0.76, –0.03)**	**(0.028)**
Minor employment	–0.46 (–1.45, 0.54)	(1.000)
Unemployed	**1.20 (0.04, 2.38)**	**(0.035)**
No. Public Transfers	11.98 (–19.66, 56.09)	(1.000)
ALG I/II	0.06 (–0.80, 0.92)	(1.000)
SI		
Moved last Year	**–2.13 (–3.52, –0.72)**	**(0.000)**
Single	0.46 (–0.42, 1.35)	(0.639)
One-Person-Household	**1.65 (0.09, 3.23)**	**(0.033)**
SES × SI Interactions		
ISEI (inv.) × Single	0.27 (–0.73, 1.28)	(1.000)
CASMIN (inv.) × Single	–0.96 (–2.16, 0.26)	(0.297)
Income (inv.) × Single	**0.54 (0.01, 1.07)**	**(0.036)**
ISEI (inv.) × One-Person-Household	–1.15(2.34, –0.05)	(0.072)
CASMIN (inv.) × One-Person-Household	–0.72 (–2.43, 1.03)	(1.000)
Income (inv.) × One-Person-Household	**–0.98 (–1.79, –0.17)**	**(0.009)**
ISEI (inv.) × Moved last Year	–0.29 (–2.37, 1.84)	(1.000)
CASMIN (inv.) × Moved last Year	**3.52 (1.20, 5.91)**	**(0.000)**
Income (inv.) × Moved last Year	0.15 (–0.63, 0.93)	(1.000)
Observations	5070	

The table reports percentage changes of r_{dt} with Bonferroni corrected 95% confidence intervals in square brackets and Bonferroni corrected p-values in parentheses. Control variables are not shown. Results significant at $\alpha = 0.05$ are printed in bold. "inv." is abbreviated from inverted.
Source: German Microcensus & Death Record, 1997 to 2010, & 2013 European Standard Population - ed. by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

Mean values of ISEI, CASMIN and income presumed, a percentage point increase in district population shares of people living in a one-person-household is shown to be associated with an increase in district suicide rates by 1.65% ($p < 0.033$). An increase in persons moving throughout the last year by 1% is found to decrease suicide rates by −2.13% ($p < 0.000$), though.

Regarding interactions of SES and SI, a 1% decrease in the incomes of the respective district's single persons increases district suicide rates by 0.54% ($p < 0.036$). In addition to this, a decrease in CASMIN scores among individuals with a recent relocation of 1% is associated with an increase in suicide rates by 3.52% ($p < 0.000$). By contrast, a 1% decrease in the incomes of district individuals living in one-person-households results in a −0.98% decrease in suicide rates ($p < 0.009$).

DISCUSSION

In light of these results, an inverse relation between SES and suicide rates as claimed by Hypothesis I is partly confirmed by the observed unemployment and income effects. This finding is contradicted by the observation that suicide rates increase with increases in CASMIN scores, however. Due to the employed aggregate data, a reasonable explanation for this finding may exist in district compositions: Average CASMIN levels have been steadily increasing over the entire observation period in Germany (68). Given that the specification of our model does not allow to differentiate between effects of individual characteristics and district composition, it can not be excluded by the observed positive effect that the corresponding individuals boast disproportionally low suicide risks. The same reasoning applies to the results in line with Hypothesis I: Given the data, our model specification does not rule out disproportionally low suicide numbers among unemployed individuals and persons with lower household incomes as compared to employees and individuals with higher incomes.

With regard to SI effects on suicide, the coefficient estimates of the district proportion of persons living in one-person-households partly validate an inverse relation between SI and suicide rates as stated by Hypothesis II. This result also confirms Agerbo et al.'s (38) findings. As these observations represent compound individual and district composition effects, it needs to be noted that our results do not eliminate the possibility that the concerning individuals show lower suicide risks if compared to persons who live in more-than-one-person-households. Vice versa, this is also valid for the negative effects on suicides found for district share increases of individuals moving throughout the year preceding suicide, contradicting Hypothesis II: At the district level, high resident turnover rates prevailing in areas with relatively low suicide rates, e.g. rural regions (69, 70), provide a potential explanation for this observation. This does not preclude higher suicide risks among moving as opposed to non-moving individuals, though.

Moreover, the positive effects of income decreases in population shares of single persons on district suicide rates corroborate the *SES* × *SI* interactions proposed by Hypothesis III. Another confirmation is suggested by the estimate that shows an increase in suicide rates to be associated with CASMIN score decreases in persons who moved during the past year. On the contrary, the observed negative effects on suicides of decreases in household incomes of the districts' persons living in one-person-households clearly contradict the claimed interactions. Once more compositional effects may be a possible reason for the inconsistent observations. Thus, it cannot be ruled out that individuals living in one-person-households who committed suicide show comparatively low income levels. This may hold even true if the means of the respective marginal distributions increase with ascending suicide rates across $N \times T = 5{,}460$ district observations. The same argument applies to the findings confirming Hypothesis III: Incomes in single persons and CASMIN scores in relocated individuals might increase in districts with ascending suicide rates considering the aggregate data employed in this study.

In view of the inconsistent results regarding Hypotheses I to III, it is generally recommended that future studies should incorporate individual level data in order to separate individual level from district composition effects and further investigate the robustness of our observations. Nonetheless, the results demonstrating positive SES and SI effects on suicide rates serve as appropriate starting points for the development of suicide prevention strategies: First, our findings suggest interventions to especially target the unemployed, individuals living in one-person-households, persons with low incomes and relocated individuals with lower educational levels. In a second step, specific strategies should be designed in order to cover the needs of the individuals under concern. In order to do so, future work should focus on the causal mechanisms resulting in suicidality. This is best accomplished by applying longitudinal data and modeling life course interactions of adversities and mental health. Depending on the results, respective programs may then include alliances between psychiatric centers and welfare offices lowering the threshold for unemployed and poorly earning individuals to seek counseling and treatment. For socially isolated individuals, effective interventions may encompass approaches aiming at the conditions that favor social isolation within local communities. Respective strategies could also involve the strengthening of communal support systems as well as the improvement of transport services and communication technologies. In addition to this, direct interventions may be established that help individuals in maintaining or developing interpersonal connections (71).

AUTHOR CONTRIBUTIONS

A-FN conceptualized the study. A-FN, CR-K, and UH designed the study. A-FN undertook the statistical analyses. A-FN, CR-K, and UH interpreted the data. A-FN drafted the manuscript. CR-K and UH critically revised the draft for important intellectual content. All the authors approved the final version of the manuscript.

FUNDING

The authors acknowledge support from the German Research Foundation (DFG) and Leipzig University within the program

of Open Access Publishing. Funding for the provision of the Data by the German Federal Statistical Office (DESTATIS) was provided by UH.

ACKNOWLEDGMENTS

The authors would like to thank Professor Dr. Georg Schomerus, University of Leipzig, Germany, Professor Dr. Bernhard Boockmann, IAW Tübingen, Germany, and Dr. Stephan Poppe, University of Leipzig, Germany, as well as the staff from the German Federal Statistical Agency (DESTATIS) for their outstanding support.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2019.00898/full#supplementary-material

REFERENCES

1. WHO. Global Health Observatory data repository. (2018). Suicide rate estimates, age-standardized Estimates by WHO region.
2. EU. *EU-Compass for Action on Mental Health and Wellbeing. Annual Report 2017. Summary and Analysis of Key Developments in Members States and Stakeholders*. European Commision: Brussels (2017).
3. UN. SDG Indicators Metadata repository. (2018).
4. Rehkopf D, Buka S. The association between suicide and the socio-economic characteristics of geographical areas: a systematic review. *Psychol Med* (2006) 36:145–7. doi: 10.1017/s003329170500588x
5. Stuckler D, Basu S, Suhrcke M, Coutts A, McKee M. The public health effect of economic crises and alternative policy responses in Europe: an empirical analysis. *Lancet* (2009) 374:315–3. doi: 10.1016/s0140-6736(09)61124-7
6. Milner A, McClure R, De Leo D. Socio-economic determinants of suicide: an ecological analysis of 35 countries. *Social Psychiatry Psychiatric Epidemiol* (2012) 47:19–7. doi: 10.1007/s00127-010-0316-x
7. Baller RD, Richardson KK. Social integration, imitation, and the geographic patterning of suicide. *Am Sociological Rev* (2002) 67(6):873–8. doi: 10.2307/3088974
8. Barkan SE, Rocque M, Houle J. State and regional suicide rates: a new look at an old puzzle. *Sociological Perspect* (2013) 56:287–7. doi: 10.1525/sop.2013.56.2.287
9. Smith NDL, Kawachi I. State-level social capital and suicide mortality in the 50 US states. *Social Sci Med* (2014) 120:269–7. doi: 10.1016/j.socscimed.2014.09.007
10. Turecki G, Ernst C, Jollant F, Labonté B, Mechawar N. The neurodevelopmental origins of suicidal behavior. *Trends Neurosci* (2012) 35:14–3. doi: 10.1016/j.tins.2011.11.008
11. Turecki G, Brent DA. Suicide and suicidal behaviour. *Lancet* (2016) 387:1227–9. doi: 10.1016/s0140-6736(15)00234-2
12. Li Z, Page A, Martin G, Taylor R. Attributable risk of psychiatric and socio-economic factors for suicide from individual-level, population-based studies: a systematic review. *Social Sci Med* (2011) 72:608–6. doi: 10.1016/j.socscimed.2010.11.008
13. Lorant V, de Gelder R, Kapadia D, Borrell C, Kalediene R, Kovács K, et al. Socioeconomic inequalities in suicide in Europe: the widening gap. *British J Psychiatry* (2018) 212(6):356–61. doi: 10.1192/bjp.2017.32
14. Milner A, Page A, Lamontagne AD. Cause and effect in studies on unemployment, mental health and suicide: a meta-analytic and conceptual review. *Psychol Med* (2014) 44:909–7. doi: 10.1017/s0033291713001621
15. Pan YJ, Stewart R, Chang CK. Socioeconomic disadvantage, mental disorders and risk of 12-month suicide ideation and attempt in the national comorbidity survey replication (NCS-R) in US. *Social Psychiatry Psychiatric Epidemiol* (2013) 48:71–9. doi: 10.1007/s00127-012-0591-9
16. Hiyoshi A, Kondo N, Rostila M. Increasing income-based inequality in suicide mortality among working-age women and men, Sweden, 1990–2007: is there a point of trend change? *J Epidemiol Community Health* (2018) 72:1009–5. doi: 10.1136/jech-2018-210696
17. Huang X, Ribeiro JD, Musacchio KM, Franklin JC. Demographics as predictors of suicidal thoughts and behaviors: a meta-analysis. *PloS ONE* (2017) 12:e0180793. doi: 10.1371/journal.pone.0180793
18. Chan LF, Shamsul AS, Maniam T. Are predictors of future suicide attempts and the transition from suicidal ideation to suicide attempts shared or distinct: a 12-month prospective study among patients with depressive disorders. *Psychiatry Res* (2014) 220:867–3. doi: 10.1016/j.psychres.2014.08.055
19. Lukaschek K, Baumert J, Krawitz M, Erazo N, Förstl H, Ladwig KH. Determinants of completed railway suicides by psychiatric in-patients: case–control study. *British J Psychiatry* (2014) 205:398–6. doi: 10.1192/bjp.bp.113.139352
20. Fryers T, Melzer D, Jenkins R. Social inequalities and the common mental disorders. *Social Psychiatry Psychiatric Epidemiol* (2003) 38:229–7. doi: 10.1007/s00127-003-0627-2
21. Jenkins R, Bhugra D, Bebbington P, Brugha T, Farrell M, Coid J, et al. Debt, income and mental disorder in the general population. *Psychol Med* (2008) 38:1485–3. doi: 10.1017/s0033291707002516
22. Bjelland I, Krokstad S, Mykletun A, Dahl AA, Tell GS, Tambs K. Does a higher educational level protect against anxiety and depression? The HUNT study. *Social Sci Med* (2008) 66:1334–5. doi: 10.1016/j.socscimed.2007.12.019
23. Lund C, Breen A, Flisher AJ, Kakuma R, Corrigall J, Joska JA, et al. Poverty and common mental disorders in low and middle income countries: a systematic review. *Social Sci Med* (2010) 71:517–8. doi: 10.1016/j.socscimed.2010.04.027
24. Chesney E, Goodwin GM, Fazel S. Risks of all-cause and suicide mortality in mental disorders: a meta-review. *World Psychiatry* (2014) 13:153–0. doi: 10.1002/wps.20128
25. Ferrari AJ, Norman RE, Freedman G, Baxter AJ, Pirkis JE, Harris MG, et al. The burden attributable to mental and substance use disorders as risk factors for suicide: findings from the global burden of disease study 2010. *PloS One* (2014) 9:e91936. doi: 10.1371/journal.pone.0091936
26. Hjelmeland H, Dieserud G, Dyregrov K, Knizek BL, Leenaars AA. Psychological autopsy studies as diagnostic tools: are they methodologically flawed? *Death Studies* (2012) 36:605–6. doi: 10.1080/07481187.2011.584015
27. Kristensen P, Gravseth HM, Bjerkedal T. Influence of early life factors on social inequalities in psychiatric outcomes among young adult Norwegian men. *Eur J Public Health* (2010) 20:517–3. doi: 10.1093/eurpub/ckq083
28. Quesnel-Vallée A, Taylor M. Socioeconomic pathways to depressive symptoms in adulthood: evidence from the National Longitudinal Survey of Youth 1979. *Social Sci Med* (2012) 74:734–3. doi: 10.1016/j.socscimed.2011.10.038
29. Lin N. *Social Capital: A Theory of Social Structure and Action*. Cambridge University Press: New York (2001). doi: 10.1017/cbo9780511815447
30. Joiner TE. *Why people die by suicide*. Harvard University Press: Cambridge, MA, US (2005).
31. Qin P, Agerbo E, Mortensen P. Suicide risk in relation to socioeconomic, demographic, psychiatric, and familial factors: a national register–based study of all suicides in Denmark, 1981–1997. *Am J Psychiatry* (2003) 160:765–2. doi: 10.1176/appi.ajp.160.4.765
32. Johansson LM, Sundquist J, Johansson SE, Qvist J, Bergman B. The influence of ethnicity and social and demographic factors on Swedish suicide rates. *Social Psychiatry Psychiatric Epidemiol* (1997) 32:165–0. doi: 10.1007/BF00794616
33. Kposowa AJ. Marital status and suicide in the National Longitudinal Mortality Study. *J Epidemiol Community Health* (2000) 54:254–1. doi: 10.1136/jech.54.4.254
34. Yip PS, Thorburn J. Marital status and the risk of suicide: experience from England and Wales 1982–1996. *Psychol Rep* (2004) 94:401–7. doi: 10.2466/pr0.94.2.401-407

35. Martikainen P, Mäki N, Blomgren J. The effects of area and individual social characteristics on suicide risk: a multilevel study of relative contribution and effect modification. *Eur J Popul* (2004) 20:323–0. doi: 10.1007/s10680-004-3807-1
36. Lorant V, Kunst AE, Huisman M, Bopp M, Mackenbach J. A European comparative study of marital status and socio-economic inequalities in suicide. *Social Sci Med* (2005) 60:2431–1. doi: 10.1016/j.socscimed.2004.11.033
37. Burrows S, Auger N, Gamache P, St-Laurent D, Hamel D. Influence of social and material individual and area deprivation on suicide mortality among 2.7 million Canadians: a prospective study. *BMC Public Health* (2011) 11:1–11. doi: 10.1186/1471-2458-11-577
38. Agerbo E, Sterne J, Gunell D. Combining individual and ecological data to determine compositional and contextual socioeconomic risk factors for suicide. *Social Sci Med* (2007) 64:451–1. doi: 10.1016/j.socscimed.2006.08.043
39. Qin P, Mortensen PB, Pedersen CB. Frequent change of residence and risk of attempted and completed suicide among children and adolescents. *Archives Gen Psychiatry* (2009) 66:628–2. doi: 10.1001/archgenpsychiatry.2009.20
40. Bramson LM, Rickert ME, Class QA, Sariaslan A, Almqvist C, Larsson H, et al. The association between childhood relocations and subsequent risk of suicide attempt, psychiatric problems, and low academic achievement. *Psychol Med* (2016) 46:969–9. doi: 10.1017/s0033291715002469
41. Alexopoulos GS. Depression in the elderly. *Lancet* (2005) 365:1961–0. doi: 10.1016/s0140-6736(05)66665-2
42. Conwell Y, Duberstein PR, Hirsch JK, Conner KR, Eberly S, Caine ED. Health status and suicide in the second half of life. *Int J Geriatric Psychiatry: A J Psychiatry late life allied Sci* (2010) 25:371–9. doi: 10.1002/gps.2348
43. Barnett PA, Gotlib IH. Psychosocial functioning and depression: distinguishing among antecedents, concomitants, and consequences. *Psychol Bulletin* (1988) 104:97. doi: 10.1037/0033-2909.104.1.97
44. Kawachi I, Berkman LF. Social ties and mental health. *J Urban Health* (2001) 78:458–7. doi: 10.1093/jurban/78.3.458
45. Santini ZI, Koyanagi A, Tyrovolas S, Haro JM. The association of relationship quality and social networks with depression, anxiety, and suicidal ideation among older married adults: findings from a cross-sectional analysis of the Irish Longitudinal Study on Ageing (TILDA). *J Affective Disorders* (2015) 179:134–1. doi: 10.1016/j.jad.2015.03.015
46. Hirschfeld R, Montgomery SA, Keller MB, Kasper S, Schatzberg AF, Möller HJ, et al. Social functioning in depression: a review. *J Clin Psychiatry* (2000) 61:268–5. doi: 10.4088/jcp.v61n0405
47. Taylor SE, Stanton AL. Coping resources, coping processes, and mental health. *Ann Rev Clin Psychol* (2007) 3:377–1. doi: 10.1146/annurev.clinpsy.3.022806.091520
48. Thoits PA. Stress and health major findings and policy implications. *J Health Social Behav* (2010) 51:S41–3. doi: 10.1177/0022146510383499
49. Holahan C, Moos R, Holahan C, Brennan P. Social context, coping strategies, and depressive symptoms: an expanded model with cardiac patients. *J Personality Social Psychol* (1997) 72:918–8. doi: 10.1037/0022-3514.72.4.918
50. Schroevers MJ, Ranchor AV, Sanderman R. The role of social support and self-esteem in the presence and course of depressive symptoms: a comparison of cancer patients and individuals from the general population. *Social Sci Med* (2003) 57:375–5. doi: 10.1016/s0277-9536(02)00366-0
51. Khatib Y, Bhui K, Stansfeld SA. Does social support protect against depression & psychological distress? Findings from the RELACHS study of East London adolescents. *J Adolesc* (2013) 36:393–2. doi: 10.1016/j.adolescence.2013.01.001
52. Suvak M, Taft C, Goodman L, Dutton M. Dimensions of functional social support and depressive symptoms: a longitudinal investigation of women seeking help for intimate partner violence. *J Consulting Clin Psychol* (2013) 81:455–6. doi: 10.1037/a0031787
53. WHO. (1976). *The ninth revision of the International Classification of Diseases (ICD-9)* (Geneva: World Health Organization).
54. WHO. *The tenth revision of the International Classification of Diseases (ICD-10)* (Geneva: World Health Organization) (1992).
55. Hegerl U, Mergl R, Doganay G, Reschke K, Rummel-Kluge C. Why has the continuous decline in German suicide rates stopped in 2007? *PLoS ONE* (2013) 8:1–9. doi: 10.1371/journal.pone.0071589
56. König W, Lüttinger P, Müller W. A comparative analysis of the development and structure of educational systems. Methodological foundations and the construction of a comparative educational scale. In: *University of Mannheim: CASMIN-Project. Working Paper No. 12* (1988).
57. Brauns H, Steinmann S. Educational reform in France, West-Germany and the United Kingdom: updating the CASMIN educational classification. *ZUMA Nachrichten* (1999) 23:7–44.
58. Ganzeboom HB, Treiman DJ. Internationally comparable measures of occupational status for the 1988 International Standard Classification of Occupations. *Social Sci Res* (1996) 25:201–9. doi: 10.1006/ssre.1996.0010
59. Schmidtke A, Sell R, Löhr C. Epidemiologie von Suizidalität im Alter. *Zeitschrift für Gerontologie und Geriatrie* (2008) 41:3–13. doi: 10.1007/s00391-008-0517-z
60. Prentice R, Sheppard L. Aggregate data studies of disease risk factors. *Biometrika* (1995) 82:113–5. doi: 10.1093/biomet/82.1.113
61. Lee LF, Yu J. Estimation of spatial autoregressive panel data models with fixed effects. *J Econometrics* (2010) 154:165–5. doi: 10.1016/j.jeconom.2009.08.001
62. Wooldridge JM. *Econometric analysis of cross section and panel data*. The MIT Press: Cambridge, Massachusetts (2010).
63. Nakamura A, Nakamura M. On the relationships among several specification error tests presented by Durbin, Wu, and Hausman. *Econometrica: J Econometric Soc* (1981), 49:1583–8. doi: 10.2307/1911420
64. Kiviet JF. On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. *J Econometrics* (1995) 68:53–8. doi: 10.1016/0304-4076(94)01643-e
65. Bun MJ, Kiviet JF. On the diminishing returns of higher-order terms in asymptotic expansions of bias. *Econ Letters* (2003) 79:145–2. doi: 10.1016/s0165-1765(02)00299-9
66. Koyck LM. *Distributed lags and investment analysis*. North-Holland Publishing Company: Amsterdam (1954).
67. Greenland S. A review of multilevel theory for ecologic analysis. *Stat Med* (2002) 21:389–5. doi: 10.1002/sim.1024
68. Moor I, Günther S, Knöchelmann A, Hoebel J, Pförtner TK, Lampert T, et al. Educational inequalities in subjective health in Germany from 1994 to 2014: a trend analysis using the German Socio-Economic Panel study (GSOEP). *BMJ Open* (2018) 8:e019755. doi: 10.1136/bmjopen-2017-019755
69. Hempstead K. The geography of self-injury: Spatial patterns in attempted and completed suicide. *Social Sci Med* (2006) 62:3186–6.
70. Santana P, Costa C, Cardoso G, Loureiro A, Ferrão J. Suicide in Portugal: Spatial determinants in a context of economic crisis. *Health Place* (2015) 35:85–4. doi: 10.1016/j.healthplace.2015.07.001
71. Jopling K, Vasileiou K. (2015). *Promising approaches to reducing loneliness and isolation in later life (Age UK - Campaign to end loneliness)* (Age UK - Campaign to end loneliness).

Conflict of Interest: PD Dr. CR-K reports personal fees from Servier, outside the submitted work. Professor Dr. UH reports personal fees from Lundbeck, personal fees from Servier, personal fees from Bayer Pharma, grants from Medice Arzneimittel, and personal fees from Roche, outside the submitted work.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Zusammenfassung der Arbeit

Dissertation zur Erlangung des akademischen Grades Dr. med.

Assessing Associations of Suicide with Socioeconomic Status and Social Isolation

eingereicht von
Anatol-Fiete Näher M.A.

angefertigt an der
Klinik und Poliklinik für Psychiatrie und Psychotherapie
der medizinischen Fakultät der Universität Leipzig

betreut von
Professorin Dr. med. Christine Rummel-Kluge

Februar 2020

With yearly rates ranking clearly above world average in Europe, suicide constitutes a substantial public health problem. Because of that, prevention has become a major concern for German mental health institutions. A requirement for successful prevention strategies is to address all key factors that contribute to suicidality. It is highly relevant in this respect that suicidal behaviour itself exhibits a social gradient: drawing on the relevant literature, low socioeconomic status (SES) and a high extent of social isolation (SI) are related to increased suicide risks (Lorant et al. 2005; Li et al. 2011; Qin et al. 2003; Agerbo et al. 2007). The purpose of this study was therefore to add to these findings and to further investigate associations of SES and SI with suicide in order to define starting points for public health interventions. It was consequently hypothesized that lower individual levels of SES and higher individual levels of SI are correlated with increased suicide rates. SI potentially compromises the perception of social support in stressful live events associated with low SES (Cohen et al. 2006; Kumari et al. 2010). Since such life events correlate with suicidal behavior (Beautrais et al. 1997; Cohen et al. 2019), the effects of low SES were further

hypothesized to be aggravated in individuals with high SI levels (SES × SI interaction).

In order to test the hypotheses, all 149.033 suicide deaths between 1997 and 2010 ($T = 14$ years) were extracted from the official German death record as coded by ICD categories E950 - E959 for 1997 and X60 - X84 for the years from 1998 onwards, respectively. Information on SES and SI was gained by merging the dataset with Germany's main household survey, i.e. the Microcensus. In accordance with the existing literature, established indexes on occupational status (ISEI, Ganzeboom & Treiman 1996) and educational achievements (CASMIN, König et al. 1988) were applied as well as items on income, minor employment, unemployment, the number of received public transfers and the reception of social benefits due to unemployment (ALG I/II) in order to capture SES. SI was proxied with variables measuring single marital status, living in a one-person-household and relocations throughout the year before the survey was conducted.

Due to German data protection regulations that do not permit the analysis of death record data based on individual level information, suicide deaths were examined as aggregated rates at the level of $N = 390$ administrative districts. In order to deal with two problems associated with this kind of statistical analysis, Prentice and Sheppard's model for aggregate data (1995) was applied accounting for potential estimation biases due to differences in baseline suicide rates between districts and between time periods. The model specification further corrected for spatial effect correlations. An important limitation to this procedure is that the estimates represent a blend of effects at the individual and district levels. However, an adequate solution is only available through the application of individual level data.

The statistical analysis turned out the following results: The positive effect on suicide rates of unemployment and the negative effect of income as two out of seven SES proxies and the positive effect of living in a one-person-household as one out of three SI proxies validate the proposed hypotheses on the relations of SES and SI with suicide rates. Confirming the hypothesis on SI mediating SES effects, the model revealed positive effects on suicide rates of income decreases in single individuals. Likewise, we observed positive effects on district suicide rates for decreasing levels of CASMIN in district population shares who had relocated throughout the past year. In contradiction to the theoretical claims, however, increases in CASMIN scores were found to result in positive effects on suicide rates just as a history of relocation prior to suicide was related to decreasing suicide rates. Furthermore, decreases in income were found to result in negative effects on suicide rates in the district population of persons living in a one-person-household.

The results indicating associations of SES and SI with increases in district suicide rates repre-

sent appropriate starting points for the definition of suicide prevention strategies. Thus, particularly the unemployed, individuals with low incomes, persons living in one-person-households and relocated individuals with lower educational levels should be targeted by public health interventions. Moreover, the observations of the present study clearly demonstrate the significance of longitudinal individual level data for public health policies. Respective research incorporating such data would permit a better understanding of the causal mechanisms resulting in suicidality and help to further investigate the robustness of the shown results. By this means, prevention strategies could be better adapted to the specific needs of the individuals under concern. Regarding the findings contradicting the theoretical claims, it needs to be mentioned that associations of low SES and high SI levels with increases in suicide risks can not be ruled out at the individual level. Rather, the observed inconsistent effects might be attributable to differences in district compositions than to differences in characteristics of the respective subjects. Also a statistical separation of compositional effects from effects of individual traits would be made possible by including individual level data in future work.

References

Adler, N., Bush, N. & Pantell, M. (2012). Rigor, vigor, and the study of health disparities. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(2), 17154–17159.

Adler, N., Cutler, D., Jonathan, J., Galea, S., Glymour, M., Koh, H. & Satcher, D. (2016). Addressing social determinants of health and health disparities. *National Academy of Medicine*, 1–16.

Agerbo, E., Sterne, J. & Gunell, D. (2007). Combining individual and ecological data to determine compositional and contextual socioeconomic risk factors for suicide. *Social Science & Medicine*, *64*, 451–461.

Alexopoulos, G. S. (2005). Depression in the elderly. *The Lancet*, *365*(9475), 1961–1970.

Anacker, C. & Pariante, C. (2012). Can adult neurogenesis buffer stress responses and depressive behaviour? *Molecular Psychiatry*, *17*, 9–10.

Antonovsky, A. (1967). Social class, life expectancy and overall mortality. *The Milbank Memorial Fund Quarterly*, *45*, 31–73.

Badanes, L. S., Watamura, S. E. & Hankin, B. L. (2011). Hypocortisolism as a potential marker of allostatic load in children: associations with family risk and internalizing disorders. *Development and Psychopathology*, *23*(3), 881–896.

Banerjee, S., Chatterji, P. & Lahiri, K. (2017). Effects of psychiatric disorders on labor market outcomes: a latent variable approach using multiple clinical indicators. *Health Economics*, *26*(2), 184–205.

Beautrais, A. L., Joyce, P. R. & Mulder, R. T. (1997). Precipitating factors and life events in serious suicide attempts among youths aged 13 through 24 years. *Journal of the American Academy of Child & Adolescent Psychiatry*, *36*(11), 1543–1551.

Ben-Shlomo, Y. & Kuh, D. (2002). *A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives.* Oxford University Press.

Berkman, L., Glass, T., Brisette, I. & Seeman, T. (2000). From social integration to health: Durkheim in the new millennium. *Social Science & Medicine*, *51*, 843–857.

Blakely, T. A., Collings, S. C. & Atkinson, J. (2003). Unemployment and suicide. Evidence for a causal association? *Journal of Epidemiology & Community Health*, *57*(8), 594–600.

Bloom, D. E., Cafiero, E., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L. R., Fathima, S., Feigl, A. B., Gaziano, T., Hamandi, A., Mowafi, M. et al. (2012). *The global economic burden of noncommunicable diseases* (Tech. Rep.). Harvard University, Program on the Global Demography of Aging.

Bolton, J., Walld, R., Chateau, D., Finlayson, G. & Sareen, J. (2015). Risk of suicide and suicide attempts associated with physical disorders: a population-based, balancing score-matched analysis. *Psychological Medicine*, *45*(3), 495–504.

Bor, J., Cohen, G. H. & Galea, S. (2017). Population health in an era of rising income inequality: USA, 1980–2015. *The Lancet*, *389*(10077), 1475–1490.

Breslau, J., Lane, M., Sampson, N. & Kessler, R. C. (2008). Mental disorders and subsequent educational attainment in a US national sample. *Journal of Psychiatric Research*, *42*(9), 708–716.

Brodsky, B. S. & Stanley, B. (2001). Developmental effects on suicidal behavior: the role of abuse in childhood. *Clinical Neuroscience Research*, *1*(5), 331–336.

Bruffaerts, R., Demyttenaere, K., Borges, G., Haro, J. M., Chiu, W. T., Hwang, I., Karam, E. G., Kessler, R. C., Sampson, N., Alonso, J. et al. (2010). Childhood adversities as risk factors for onset and persistence of suicidal behaviour. *The British Journal of Psychiatry*, *197*(1), 20–27.

Bun, M. J. & Kiviet, J. F. (2003). On the diminishing returns of higher-order terms in asymptotic expansions of bias. *Economics Letters*, *79*(2), 145–152.

Butterworth, P., Leach, L. S., Pirkis, J. & Kelaher, M. (2012). Poor mental health influences risk and duration of unemployment: a prospective study. *Social Psychiatry and Psychiatric Epidemiology*, *47*(6), 1013–1021.

Cassel, J. (1976). The contribution of the social environment to host resistance. *American Journal of Epidemiology*, *104*, 107–123.

Chatterji, P., Alegria, M. & Takeuchi, D. (2011). Psychiatric disorders and labor market outcomes: evidence from the National Comorbidity Survey-Replication. *Journal of Health Economics*, *30*(5), 858–868.

Chesney, E., Goodwin, G. M. & Fazel, S. (2014). Risks of all-cause and suicide mortality in mental disorders: a meta-review. *World Psychiatry*, *13*(2), 153–160.

Cleary, S. D. (2000). Adolescent victimization and associated suicidal and violent behaviors. *Adolescence*, *35*(140), 671.

Cobb, S. (1976). Social support as a moderator of life stress. *Psychosomatic Medicine*, *38*, 300–314.

Cohen, S., Doyle, W. J. & Baum, A. (2006). Socioeconomic status is associated with stress hormones. *Psychosomatic Medicine*, *68*(3), 414–420.

Cohen, S., Gianaros, P. J. & Manuck, S. B. (2016). A stage model of stress and disease. *Perspectives on Psychological Science*, *11*(4), 456–463.

Cohen, S., Kamarck, T. & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 385–396.

Cohen, S., Murphy, M. L. & Prather, A. A. (2019). Ten surprising facts about stressful life events and disease risk. *Annual Review of Psychology*, *70*, 577–597.

Costello, E., Compton, S., Keeler, G. & Angold, A. (2003). Relationships between poverty and psychopathology: a natural experiment. *The Journal of the American Medical Association*, *15*, 2023–2028.

Cougle, J. R., Resnick, H. & Kilpatrick, D. G. (2009). PTSD, depression, and their comorbidity in relation to suicidality: cross-sectional and prospective analyses of a national probability sample of women. *Depression and Anxiety*, *26*(12), 1151–1157.

Danese, A. & McEwen, B. S. (2012). Adverse childhood experiences, allostasis, allostatic load, and age-related disease. *Physiology & Behavior*, *106*(1), 29–39.

Diewald, M., Baier, T., Schulz, W. & Schunck, R. (2015). Status attainment and social mobility. *KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie*, *67*(1), 371–395.

Dohrenwend, B. P., Levav, I., Shrout, P. E., Schwartz, S., Naveh, G., Link, B. G., Skodol, A. E. & Stueve, A. (1992). Socioeconomic status and psychiatric disorders: the causation-selection issue. *Science*, *255*(5047), 946–952.

Epel, E. S., Crosswell, A. D., Mayer, S. E., Prather, A. A., Slavich, G. M., Puterman, E. & Mendes, W. B. (2018). More than a feeling: a unified view of stress measurement for population science. *Frontiers in Neuroendocrinology*, *49*, 146–169.

EU (2008). European pact for mental health and well-being. EU high-level conference "Together for mental health and well-being". Brussels, 12–13 June 2008. Slovenian Presidency of the EU 2008. *World Health Organisation/Europe*.

EU (2017). *EU-compass for action on mental health and wellbeing. annual report 2017. summary and analysis of key developments in members states and stakeholders.* Brussels: European Commision.

Evensen, M., Lyngstad, T. H., Melkevik, O., Reneflot, A. & Mykletun, A. (2017). Adolescent mental health and earnings inequalities in adulthood: evidence from the Young-HUNT Study. *Journal of Epidemiolgy & Community Health*, *71*(2), 201–206.

Fergusson, D. M. & Woodward, L. J. (2002). Mental health, educational, and social role outcomes of adolescents with depression. *Archives of General Psychiatry*, *59*(3), 225–231.

Ferrari, A. J., Norman, R. E., Freedman, G., Baxter, A. J., Pirkis, J. E., Harris, M. G., Page, A.,

Carnahan, E., Degenhardt, L., Vos, T. et al. (2014). The burden attributable to mental and substance use disorders as risk factors for suicide: findings from the global burden of disease study 2010. *PloS ONE*, *9*(4), e91936.

Flannery, D. J., Singer, M. I. & Wester, K. (2001). Violence exposure, psychological trauma, and suicide risk in a community sample of dangerously violent adolescents. *Journal of the American Academy of Child & Adolescent Psychiatry*, *40*(4), 435–442.

Ganzeboom, H. B. & Treiman, D. J. (1996). Internationally comparable measures of occupational status for the 1988 International Standard Classification of Occupations. *Social Science Research*, *25*(3), 201–239.

Giegling, I., Olgiati, P., Hartmann, A. M., Calati, R., Möller, H.-J., Rujescu, D. & Serretti, A. (2009). Personality and attempted suicide. Analysis of anger, aggression and impulsivity. *Journal of Psychiatric Research*, *43*(16), 1262–1271.

Gilman, S., Kawachi, I., Fitzmaurice, G. & Buka, S. (2002). Socioeconomic status in childhood and the lifetime risk of major depression. *International Journal of Epidemiology*, *31*, 359–367.

Goetzel, R. Z., Hawkins, K., Ozminkowski, R. J. & Wang, S. (2003). The health and productivity cost burden of the "top 10" physical and mental health conditions affecting six large US employers in 1999. *Journal of Occupational and Environmental Medicine*, *45*(1), 5–14.

Goodman, A., Joyce, R. & Smith, J. P. (2011). The long shadow cast by childhood physical and mental problems on adult life. *Proceedings of the National Academy of Sciences*, *108*(15), 6032–6037.

Guerreiro, D. F., Cruz, D., Frasquilho, D., Santos, J. C., Figueira, M. L. & Sampaio, D. (2013). Association between deliberate self-harm and coping in adolescents: a critical review of the last 10 years' literature. *Archives of Suicide Research*, *17*(2), 91–105.

Gustavsson, A., Svensson, M., Jacobi, F., Allgulander, C., Alonso, J., Beghi, E., Dodel, R., Ekman, M., Faravelli, C., Fratiglioni, L. et al. (2011). Cost of disorders of the brain in Europe 2010. *European Neuropsychopharmacology*, *21*(10), 718–779.

Gvion, Y. & Apter, A. (2011). Aggression, impulsivity, and suicide behavior: a review of the literature. *Archives of Suicide Research*, *15*(2), 93–112.

Hackman, D. A., Betancourt, L. M., Brodsky, N. L., Hurt, H. & Farah, M. J. (2012). Neighborhood disadvantage and adolescent stress reactivity. *Frontiers in Human Neuroscience*, *6*, 277.

Haynie, D. L., South, S. J. & Bose, S. (2006). Residential mobility and attempted suicide among adolescents: an individual-level analysis. *The Sociological Quarterly*, *47*(4), 693–721.

Hegerl, U., Mergl, R., Havers, I., Schmidtke, A., Lehfeld, H., Niklewski, G. & Althaus, D. (2010). Sustainable effects on suicidality were found for the Nuremberg alliance against depression. *European Archives of Psychiatry and Clinical Neuroscience*, *260*(5), 401–406.

Hegerl, U., Wittenburg, L., Arensman, E., Van Audenhove, C., Coyne, J. C., McDaid, D., Feltz-Cornelis, C. M. v. d., Gusmão, R., Kopp, M., Maxwell, M., Meise, U., Roskar, S., Sarchiapone, M., Schmidtke, A., Värnik, A. & Bramesfeld, A. (2009). Optimizing suicide prevention programs and their implementation in Europe (OSPI Europe): an evidence-based multi-level approach. *BMC Public Health*, *9*(1), 1.

Heim, C., Newport, D. J., Mletzko, T., Miller, A. H. & Nemeroff, C. B. (2008). The link between childhood trauma and depression: insights from HPA axis studies in humans. *Psychoneuroendocrinology*, *33*(6), 693–710.

Hiyoshi, A., Kondo, N. & Rostila, M. (2018). Increasing income-based inequality in suicide mortality among working-age women and men, Sweden, 1990–2007: is there a point of trend change? *Journal of Epidemiology and Community Health*, *72*(11), 1009–1015.

Hoffmann, R., Kröger, H. & Geyer, S. (2019). Social causation versus health selection in the life course: does their relative importance differ by dimension of SES? *Social Indicators Research*, *141*(3), 1341–1367.

Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T. & Stephenson, D. (2015). Loneliness and social isolation as risk factors for mortality: a meta-analytic review. *Perspectives on Psychological Science*, *10*(2), 227–237.

Holt-Lunstad, J., Smith, T. B. & Layton, J. B. (2010). Social relationships and mortality risk: a meta-analytic review. *PLoS Med*, *7*(7), e1000316.

House, R., J. & Kahn (1985). Social support and health. In S. Cohen & L. Syme (Eds.), (pp. 83–108). San Diego, CA: Academic Press.

Hudson, C. G. (2005). Socioeconomic status and mental illness: tests of the social causation and selection hypotheses. *American Journal of Orthopsychiatry*, *75*(1), 3–18.

Huurre, T., Rahkonen, O., Komulainen, E. & Aro, H. (2005). Socioeconomic status as a cause and consequence of psychosomatic symptoms from adolescence to adulthood. *Social Psychiatry and Psychiatric Epidemiology*, *40*, 580–587.

Johnson, J. G., Cohen, P., Dohrenwend, B. P., Link, B. G. & Brook, J. S. (1999). A longitudinal investigation of social causation and social selection processes involved in the association between socioeconomic status and psychiatric disorders. *Journal of Abnormal Psychology*,

108(3), 490–499.

Jokinen, J., Ouda, J. & Nordström, P. (2010). Noradrenergic function and HPA axis dysregulation in suicidal behaviour. *Psychoneuroendocrinology*, *35*(10), 1536–1542.

Judson, R. A. & Owen, A. L. (1999). Estimating dynamic panel data models: a guide for macroeconomists. *Economics Letters*, *65*(1), 9–15.

Kawachi, I., Subramanian, S. & Almeida-Filho, N. (2002). A glossary for health inequalities. *Journal of Epidemiology & Community Health*, *56*(9), 647–652.

Kawakami, N., Abdulghani, E. A., Alonso, J., Bromet, E. J., Bruffaerts, R., Caldas-de Almeida, J. M., Chiu, W. T., De Girolamo, G., De Graaf, R., Fayyad, J. et al. (2012). Early-life mental disorders and adult household income in the World Mental Health Surveys. *Biological Psychiatry*, *72*(3), 228–237.

Kendler, K. S., Thornton, L. M. & Gardner, C. O. (2000). Stressful life events and previous episodes in the etiology of major depression in women: an evaluation of the "kindling" hypothesis. *American Journal of Psychiatry*, *157*(8), 1243–1251.

Kessler, R. C., Foster, C. L., Saunders, W. B. & Stang, P. E. (1995). Social consequences of psychiatric disorders, I: Educational attainment. *American Journal of Psychiatry*, *152*(7), 1026–1032.

Kim, M.-D., Hong, S.-C., Lee, S.-Y., Kwak, Y.-S., Lee, C.-I., Hwang, S.-W., Shin, T.-K., Lee, S.-M. & Shin, J.-N. (2006). Suicide risk in relation to social class: a national register-based study of adult suicides in Korea, 1999–2001. *International Journal of Social Psychiatry*, *52*(2), 138–151.

Kiviet, J. F. (1995). On bias, inconsistency, and efficiency of various estimators in dynamic panel data models. *Journal of Econometrics*, *68*(1), 53–78.

Kleiman, E. M. & Liu, R. T. (2013). Social support as a protective factor in suicide: findings from two nationally representative samples. *Journal of Affective Disorders*, *150*(2), 540–545.

König, W., Lüttinger, P. & Müller, W. (1988). A comparative analysis of the development and structure of educational systems. Methodological foundations and the construction of a comparative educational scale. *University of Mannheim: CASMIN-Project. Working Paper No. 12*.

Kosidou, K., Dalman, C., Fredlund, P., Lee, B., Galanti, R., Isacsson, G. & Magnusson, C. (2014). School performance and the risk of suicide attempts in young adults: a longitudinal population-based study. *Psychological Medicine*, *44*(6), 1235–1243.

Koss, K. J., Hostinar, C. E., Donzella, B. & Gunnar, M. R. (2014). Social deprivation and the HPA axis in early development. *Psychoneuroendocrinology*, *50*, 1–13.

Koss, K. J., Mliner, S. B., Donzella, B. & Gunnar, M. R. (2016). Early adversity, hypocortisolism, and behavior problems at school entry: a study of internationally adopted children. *Psychoneuroendocrinology*, *66*, 31–38.

Koyck, L. M. (1954). *Distributed lags and investment analysis*. Amsterdam: North-Holland Publishing Company.

Kristensen, P., Gravseth, H. M. & Bjerkedal, T. (2010). Influence of early life factors on social inequalities in psychiatric outcomes among young adult Norwegian men. *European Journal of Public Health*, *20*(5), 517–523.

Kröger, H., Pakpahan, E. & Hoffmann, R. (2015). What causes health inequality? A systematic review on the relative importance of social causation and health selection. *The European Journal of Public Health*, *25*(6), 951–960.

Krysinska, K. & Lester, D. (2010). Post-traumatic stress disorder and suicide risk: a systematic review. *Archives of Suicide Research*, *14*(1), 1–23.

Kuh, D., Ben-Shlomo, Y., Lynch, J., Hallqvist, J. & Power, C. (2003). Life course epidemiology. *Journal of Epidemiology and Community Health*, *57*(10), 778.

Kumari, M., Badrick, E., Sacker, A., Kirschbaum, C., Marmot, M. & Chandola, T. (2010). Identifying patterns in cortisol secretion in an older population. Findings from the Whitehall II study. *Psychoneuroendocrinology*, *35*(7), 1091–1099.

Kumsta, R., Schlotz, W., Golm, D., Moser, D., Kennedy, M., Knights, N., Kreppner, J., Maughan, B., Rutter, M. & Sonuga-Barke, E. (2017). HPA axis dysregulation in adult adoptees twenty years after severe institutional deprivation in childhood. *Psychoneuroendocrinology*, *86*, 196–202.

Kupferberg, A., Bicks, L. & Hasler, G. (2016). Social functioning in major depressive disorder. *Neuroscience & Biobehavioral Reviews*, *69*, 313–332.

Kyung-Sook, W., SangSoo, S., Sangjin, S. & Young-Jeon, S. (2018). Marital status integration and suicide: a meta-analysis and meta-regression. *Social Science & Medicine*, *197*, 116–126.

Lazarus, R. S. & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

Lemaire, C. M. & Graham, D. P. (2011). Factors associated with suicidal ideation in OEF/OIF veterans. *Journal of Affective Disorders*, *130*(1-2), 231–238.

Lewis, G. & Sloggett, A. (1998). Suicide, deprivation, and unemployment: record linkage study. *BMJ*, *317*(7168), 1283–1286.

Li, Z., Page, A., Martin, G. & Taylor, R. (2011). Attributable risk of psychiatric and socio-economic factors for suicide from individual-level, population-based studies: a systematic review. *So-*

cial Science & Medicine, *72*(4), 608–616.

Lim, D., Sanderson, K. & Andrews, G. (2000). Lost productivity among full-time workers with mental disorders. *The Journal of Mental Health Policy and Economics*, *3*(3), 139–146.

Lin, N. (2001). *Social capital: A teory of social structure and action*. New York: Cambridge University Press.

Liu, R. T. & Miller, I. (2014). Life events and suicidal ideation and behavior: a systematic review. *Clinical Psychology Review*, *34*(3), 181–192.

Lorant, V., Kunst, A. E., Huisman, M., Bopp, M. & Mackenbach, J. (2005). A European comparative study of marital status and socio-economic inequalities in suicide. *Social Science & Medicine*, *60*(11), 2431–2441.

Maag, T. (2008). *Economic correlates of suicide rates in OECD countries* (Discussion Paper No. 6). St. Gallen: St. Gallen Research Centre for Ageing, Welfare and Labour Market Analysis (SCALA).

Mackenbach, J. P. et al. (2006). *Health inequalities: Europe in profile*. Produced by COI for the Department of Health.

Mackenbach, J. P., Stirbu, I., Roskam, A.-J. R., Schaap, M. M., Menvielle, G., Leinsalu, M. & Kunst, A. E. (2008). Socioeconomic inequalities in health in 22 European countries. *New England Journal of Medicine*, *358*(23), 2468–2481.

Mackenbach, J. P., Valverde, J. R., Artnik, B., Bopp, M., Brønnum-Hansen, H., Deboosere, P., Kalediene, R., Kovács, K., Leinsalu, M., Martikainen, P. et al. (2018). Trends in health inequalities in 27 European countries. *Proceedings of the National Academy of Sciences*, *115*(25), 6440–6445.

Magariños, A. M., McEwen, B. S., Flügge, G. & Fuchs, E. (1996). Chronic psychosocial stress causes apical dendritic atrophy of hippocampal CA3 pyramidal neurons in subordinate tree shrews. *The Journal of Neuroscience*, *16*(10), 3534-3540.

Mäki, N. E. & Martikainen, P. T. (2007). Socioeconomic differences in suicide mortality by sex in Finland in 1971—2000: a register-based study of trends, levels, and life expectancy differences. *Scandinavian Journal of Public Health*, *35*(4), 387–395.

Mann, J. J., Apter, A., Bertolote, J., Beautrais, A., Currier, D., Haas, A., Hegerl, U., Lonnqvist, J., Malone, K., Marusic, A. et al. (2005). Suicide prevention strategies: a systematic review. *JAMA*, *294*(16), 2064–2074.

Mann, J. J. & Currier, D. (2007). A review of prospective studies of biologic predictors of suicidal

behavior in mood disorders. *Archives of Suicide Research*, *11*(1), 3–16.

Mann, J. J. & Currier, D. (2016). The international handbook of suicide prevention. In R. O'Connor & J. Pirkis (Eds.), (pp. 149–169). John Wiley & Sons.

Mann, J. J., Currier, D., Stanley, B., Oquendo, M. A., Amsel, L. V. & Ellis, S. P. (2006). Can biological tests assist prediction of suicide in mood disorders? *International Journal of Neuropsychopharmacology*, *9*(4), 465–474.

Marmot, M. (2005). Social determinants of health inequalities. *The Lancet*, *365*(9464), 1099–1104.

Marmot, M., Friel, S., Bell, R., Houweling, T. A., Taylor, S., on Social Determinants of Health, C. et al. (2008). Closing the gap in a generation: health equity through action on the social determinants of health. *The Lancet*, *372*(9650), 1661–1669.

McEwen, B. S. (2012). Brain on stress: how the social environment gets under the skin. *Proceedings of the National Academy of Sciences*, *109*(2), 17180–17185.

Mckenzie, S., Carter, K., Blakely, T. & Collings, S. (2010). The association of childhood socioeconomic position and psychological distress in adulthood: is it mediated by adult socioeconomic position? *Longitudinal and Life Course Studies*, *1*(4), 339–358.

McLaughlin, K. A., Breslau, J., Green, J. G., Lakoma, M. D., Sampson, N. A., Zaslavsky, A. M. & Kessler, R. C. (2011). Childhood socio-economic status and the onset, persistence, and severity of DSM-IV mental disorders in a US national sample. *Social Science & Medicine*, *73*(7), 1088–1096.

McLeod, J. D. & Kaiser, K. (2004). Childhood emotional and behavioral problems and educational attainment. *American Sociological Review*, *69*(5), 636–658.

Meadows, L. A., Kaslow, N. J., Thompson, M. P. & Jurkovic, G. J. (2005). Protective factors against suicide attempt risk among African American women experiencing intimate partner violence. *American Journal of Ccommunity Psychology*, *36*(1-2), 109–121.

Melchior, M., Chastang, J.-F., Head, J., Goldberg, M., Zins, M., Nabi, H. & Younès, N. (2013). Socioeconomic position predicts long-term depression trajectory: a 13-year follow-up of the GAZEL cohort study. *Molecular Psychiatry*, *18*(1), 112–121.

Melhem, N. M., Munroe, S., Marsland, A., Gray, K., Brent, D., Porta, G., Douaihy, A., Laudenslager, M. L., DePietro, F., Diler, R. et al. (2017). Blunted HPA axis activity prior to suicide attempt and increased inflammation in attempters. *Psychoneuroendocrinology*, *77*, 284–294.

Miech, R. A., Caspi, A., Moffitt, T. E., Wright, B. E. & Silva, P. A. (1999). Low socioeconomic status and mental disorders: a longitudinal study of selection and causation during young

adulthood. *American Journal of Sociology*, *104*(4), 1096–1131.

Milner, A., Page, A. & Lamontagne, A. D. (2014). Cause and effect in studies on unemployment, mental health and suicide: a meta-analytic and conceptual review. *Psychological Medicine*, *44*(5), 909–917.

Milner, A., Spittal, M. J., Pirkis, J. & LaMontagne, A. D. (2013). Suicide by occupation: systematic review and meta-analysis. *The British Journal of Psychiatry*, *203*(6), 409–416.

Mirescu, C. & Gould, E. (2006). Stress and adult neurogenesis. *Hippocampus*, *16*(3), 233–238.

Mitra, R., Jadhav, S., McEwen, B. S., Vyas, A. & Chattarji, S. (2005). Stress duration modulates the spatiotemporal patterns of spine formation in the basolateral amygdala. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(26), 937–9376.

Mossakowski, K. N. (2008). Dissecting the influence of race, ethnicity, and socioeconomic status on mental health in young adulthood. *Research on Aging*, *30*, 649–671.

Mossakowski, K. N. (2014). The Wiley Blackwell encyclopedia of health, illness, behavior, and society. In (pp. 2154–2160). John Wiley & Sons.

Mousteri, V., Daly, M., Delaney, L., Tynelius, P. & Rasmussen, F. (2019). Adolescent mental health and unemployment over the lifespan: population evidence from Sweden. *Social Science & Medicine*, *222*, 305–314.

Nickell, S. (1981). Biases in dynamic models with fixed effects. *Econometrica*, *49*(6), 1417–1426.

O'Connor, R. C. (2011). International handbook of suicide prevention: Resarch, policy and practice. In R. C. O'Connor, S. Platt & J. Gordon (Eds.), (pp. 181–198). John Wiley & Sons.

O'Connor, R. C. & Kirtley, O. J. (2018). The integrated motivational–volitional model of suicidal behaviour. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1754), 20170268.

O'Connor, R. C. & Nock, M. K. (2014). The psychology of suicidal behaviour. *The Lancet Psychiatry*, *1*(1), 73–85.

O'Reilly, D., Rosato, M., Connolly, S. & Cardwell, C. (2008). Area factors and suicide: 5-year follow-up of the Northern Ireland population. *The British Journal of Psychiatry*, *192*(2), 106–11.

Pan, Y.-J., Stewart, R. & Chang, C.-K. (2013). Socioeconomic disadvantage, mental disorders and risk of 12-month suicide ideation and attempt in the National Comorbidity Survey Replication (NCS-R) in US. *Social Psychiatry and Psychiatric Epidemiology*, *48*(1), 71–79.

Parker, K. M., Wilson, M. G., Vandenberg, R. J., DeJoy, D. M. & Orpinas, P. (2009). Association of

comorbid mental health symptoms and physical health conditions with employee productivity. *Journal of Occupational and Environmental Medicine*, *51*(10), 1137–1144.

Patel, V., Saxena, S., Lund, C., Thornicroft, G., Baingana, F., Bolton, P., Chisholm, D., Collins, P. Y., Cooper, J. L., Eaton, J. et al. (2018). The Lancet Commission on global mental health and sustainable development. *The Lancet*, *392*(10157), 1553–1598.

Pisu, M., Garau, A., Boero, G., Biggio, F., Pibiri, V., Dore, R., Locci, V., Paci, E., Porcu, P. & Serra, M. (2016). Sex differences in the outcome of juvenile social isolation on HPA axis function in rats. *Neuroscience*, *320*, 172–182.

Platt, S. (1984). Unemployment and suicidal behaviour: a review of the literature. *Social Science & Medicine*, *19*, 93–115.

Platt, S. (2016). The international handbook of suicide prevention. In R. O'Connor & J. Pirkis (Eds.), (pp. 258–283). John Wiley & Sons.

Platt, S. & Hawton, K. (2000). The international handbook of suicide and attempted suicide. In K. Hawton (Ed.), (pp. 309–360). John Wiley & Sons.

Pollock, L. & Williams, J. (2004). Problem-solving in suicide attempters. *Psychological Medicine*, *34*(1), 163–167.

Power, C., Stansfeld, S., Matthews, S., Manor, O. & Hope, S. (2002). Childhood and adulthood risk factors for socio-economic differentials in psychological distress: evidence from the 1958 British birth cohort. *Social Science & Medicine*, *55*(11), 1989–2004.

Prentice, R. & Sheppard, L. (1995). Aggregate data studies of disease risk factors. *Biometrika*, *82*, 113–125.

Qin, P., Agerbo, E. & Mortensen, P. (2003). Suicide risk in relation to socioeconomic, demographic, psychiatric, and familial factors: a national register–based study of all suicides in Denmark, 1981–1997. *American Journal of Psychiatry*, *160*(4), 765–772.

Qin, P., Mortensen, P. B. & Pedersen, C. B. (2009). Frequent change of residence and risk of attempted and completed suicide among children and adolescents. *Archives of General Psychiatry*, *66*(6), 628–632.

Quesnel-Vallée, A. & Taylor, M. (2012). Socioeconomic pathways to depressive symptoms in adulthood: evidence from the National Longitudinal Survey of Youth 1979. *Social Science & Medicine*, *74*(5), 734–743.

Radley, J. J., Rocher, A. B., Miller, M., Janssen, W. G., Liston, C., Hof, P. R., McEwen, B. S. & Morrison, J. H. (2006). Repeated stress induces dendritic spine loss in the rat medial prefrontal

cortex. *Cerebral Cortex*, *16*(3), 313–320.

Radley, J. J., Rocher, A. B., Rodriguez, A., Ehlenberger, D. B., Dammann, M., McEwen, B. S., Morrison, J. H., Wearne, S. L. & Hof, P. R. (2008). Repeated stress alters dendritic spine morphology in the rat medial prefrontal cortex. *The Journal of Comparative Neurology*, *507*(1), 1141–1150.

Radley, J. J., Sisti, H., Hao, J., Rocher, A., McCall, T., Hof, P., McEwen, B. & Morrison, J. (2004). Chronic behavioral stress induces apical dendritic reorganization in pyramidal neurons of the medial prefrontal cortex. *Neuroscience*, *125*(1), 1–6.

Scott, K. M., Hwang, I., Chiu, W.-T., Kessler, R. C., Sampson, N. A., Angermeyer, M., Beautrais, A., Borges, G., Bruffaerts, R., De Graaf, R. et al. (2010). Chronic physical conditions and their association with first onset of suicidal behavior in the world mental health surveys. *Psychosomatic Medicine*, *72*(7), 712–719.

Shanahan, M. J. (2013). New Directions in the Sociology of Aging. In L. J. Waite & T. J. Plewes (Eds.), (pp. 255–276). Washington DC: National Academies Press (US).

Slavich, G. M. & Irwin, M. R. (2014). From stress to inflammation and major depressive disorder: a social signal transduction theory of depression. *Psychological Bulletin*, *140*(3), 774.

Slominski, L., Sameroff, A., Rosenblum, K. & Kasser, T. (2011). Longitudinal predictors of adult socioeconomic attainment: the roles of socioeconomic status, academic competence, and mental health. *Development and Psychopathology*, *23*(1), 315–324.

Sluzki, C. E. (1992). Disruption and reconstruction of networks following migration/relocation. *Family Systems Medicine*, *10*(4), 359–363.

Sonuga-Barke, E. J., Kennedy, M., Kumsta, R., Knights, N., Golm, D., Rutter, M., Maughan, B., Schlotz, W. & Kreppner, J. (2017). Child-to-adult neurodevelopmental and mental health trajectories after early life deprivation: the young adult follow-up of the longitudinal English and Romanian Adoptees study. *The Lancet*, *389*(10078), 1539–1548.

Stack, S. & Scourfield, J. (2015). Recency of divorce, depression, and suicide risk. *Journal of Family Issues*, *36*(6), 695–715.

Stansfeld, S. A., Clark, C., Rodgers, B., Caldwell, T. & Power, C. (2011). Repeated exposure to socioeconomic disadvantage and health selection as life course pathways to mid-life depressive and anxiety disorders. *Social Psychiatry and Psychiatric Epidemiology*, *46*(7), 549–558.

Stein, D. J., Chiu, W. T., Hwang, I., Kessler, R. C., Sampson, N., Alonso, J., Borges, G., Bromet, E., Bruffaerts, R., De Girolamo, G. et al. (2010). Cross-national analysis of the associations

between traumatic events and suicidal behavior: findings from the WHO World Mental Health Surveys. *PloS ONE*, *5*(5), e10574.

Sturm, R. & Gresenz, C. R. (2002). Relations of income inequality and family income to chronic medical conditions and mental health disorders: national survey. *BMJ*, *324*(7328), 20.

Surget, A., Tanti, A., Leonardo, E. D., Laugeray, A., Rainer, Q., Touma, C., Palme, R., Griebel, G., Ibarguen-Vargas, Y., Hen, R. & Belzung, C. (2011). Antidepressants recruit new neurons to improve stress response regulation. *Molecular Psychiatry*, *16*(12), 1177–1188.

Trautmann, S., Rehm, J. & Wittchen, H.-U. (2016). The economic costs of mental disorders. *EMBO Reports*, *17*(9), 1245–1249.

Turecki, G. (2014). The molecular bases of the suicidal brain. *Nature Reviews Neuroscience*, *15*(12), 802–816.

Turecki, G. & Brent, D. A. (2016). Suicide and suicidal behaviour. *The Lancet*, *387*(10024), 1227 - 1239.

Turecki, G., Ernst, C., Jollant, F., Labonté, B. & Mechawar, N. (2012). The neurodevelopmental origins of suicidal behavior. *Trends in Neurosciences*, *35*(1), 14–23.

UN (2018). *SDG Indicators Metadata repository.* Retrieved from `https://unstats.un.org/sdgs/metadata/`, `accessed 28 August 2018`

Ursache, A. & Noble, K. G. (2016). Neurocognitive development in socioeconomic context: Multiple mechanisms and implications for measuring socioeconomic status. *Psychophysiology*, *53*(1), 71–82.

Virchow, R. (1848). Die öffentliche Gesundheitspflege. *Die medicinische Reform*, *1*(9), 53–56.

Vliegenthart, J., Noppe, G., Van Rossum, E., Koper, J., Raat, H. & Van den Akker, E. (2016). Socioeconomic status in children is associated with hair cortisol levels as a biological measure of chronic stress. *Psychoneuroendocrinology*, *65*, 9–14.

Vyas, A., Jadhav, S. & Chattarji, S. (2006). Prolonged behavioral stress enhances synaptic connectivity in the basolateral amygdala. *Neuroscience*, *143*(2), 387–393.

Vyas, A., Mitra, R., Rao, B. S. & Chattarji, S. (2002). Chronic stress induces contrasting patterns of dendritic remodeling in hippocampal and amygdaloid neurons. *The Journal of Neuroscience*, *22*(15), 6810–6818.

Wadsworth, M. E. & Achenbach, T. M. (2005). Explaining the link between low socioeconomic status and psychopathology: testing two mechanisms of the social causation hypothesis.

Journal of Consulting and Clinical Psychology(6), 1146–1153.

Walsh, S. D., Levine, S. Z. & Levav, I. (2012). The association between depression and parental ethnic affiliation and socioeconomic status: a 27-year longitudinal US community study. *Social Psychiatry and Psychiatric Epidemiology*, *47*(7), 1153–1158.

Wasserman, D., Rihmer, Z., Rujescu, D., Sarchiapone, M., Sokolowski, M., Titelman, D., Zalsman, G., Zemishlany, Z. & Carli, V. (2012). The European Psychiatric Association (EPA) guidance on suicide treatment and prevention. *European Psychiatry*, *27*(2), 129–141.

Wasserman, D., Wasserman, J., Rozanov, V. & Sokolowski, M. (2009). Depression in suicidal males: genetic risk variants in the CRHR1 gene. *Genes, Brain and Behavior*, *8*(1), 72–79.

Watanabe, Y., Gould, E. & McEwen, B. S. (1992). Stress induces atrophy of apical dendrites of hippocampal CA3 pyramidal neurons. *Brain Research*, *588*(2), 341–345.

Webb, R. T., Kontopantelis, E., Doran, T., Qin, P., Creed, F. & Kapur, N. (2012). Suicide risk in primary care patients with major physical diseases: a case-control study. *Archives of General Psychiatry*, *69*(3), 256–264.

Weiss, I. C., Pryce, C. R., Jongen-Rêlo, A. L., Nanz-Bahr, N. I. & Feldon, J. (2004). Effect of social isolation on stress-related behavioural and neuroendocrine state in the rat. *Behavioural Brain Research*, *152*(2), 279–295.

Wellman, C. L. (2001). Dendritic reorganization in pyramidal neurons in medial prefrontal cortex after chronic corticosterone administration. *Journal of Neurobiology*, *49*(3), 245–253.

WHO (1976). *The ninth revision of the International Classification of Diseases (ICD-9).* Geneva: World Health Organization.

WHO (1992). *The tenth revision of the International Classification of Diseases (ICD-10).* Geneva: World Health Organization.

WHO (2011). Rio political declaration on social determinants of health. In *World Conference on Social Determinants of Health, Rio de Janeiro* (pp. 19–21). Geneva.

WHO (2012). *Public health action for the prevention of suicide: A framework.* Geneva: World Health Organization.

WHO (2018). *Global Health Observatory data repository. Suicide rate estimates, age-standardized Estimates by WHO region.* Geneva. Retrieved from `http://apps.who.int/gho/data/view.main.MHSUICIDEASDRREGv?lang=en`, accessed 28 August 2018

Yang, B. & Clum, G. A. (1994). Life stress, social support, and problem-solving skills predictive of

depressive symptoms, hopelessness, and suicide ideation in an Asian student population: a test of a model. *Suicide and Life-Threatening Behavior*, *24*(2), 127–139.

Zimmerman, F. J. & Katon, W. (2005). Socioeconomic status, depression disparities, and financial strain: what lies behind the income-depression relationship? *Health Economics*, *14*(12), 1197–1215.

Supplementary Materials - Further Statistical Tests & Models

Structural Breaks in Suicide Numbers

Following Maag (2008), structural breaks in reported suicide numbers due to ICD revisions can be detected given:

$$\Delta y_{dt} = \phi z_t + v_t + t\gamma_d + \eta_{dt}, \tag{1}$$

where $\Delta y_{dt} = y_{dt} - y_{dt-1}$. t represents the year, d the district and v_t a time fixed effect. $t\gamma_d$ is a district specific time trend. Further, the dummy z_t indicates the year of the ICD revision. An error is given by $\eta_{dt} \sim N(0, \sigma_\eta^2)$. According to this specification, the coefficients ϕ identify an effect that is induced by an exogenous shock during the year of the ICD revision, the revision itself or both.

	POLS Suicides per District Yearly Change	
	ϕ [95% - CI]	**p-value**
Year of ICD Revision	-0.38 [-0.87, 0.12]	(0.14)
N	5070	

Notes: 95% confidence intervals are shown in square brackets, *p*-values in parentheses. Results significant at $\alpha = 0.05$ are printed in **bold**.
Source: German Death Record, 1997 to 2010 - ed. by the German federal statistical office (DESTATIS), own calculations were performed with STATA 15.0.

Table 1: POLS Regression of yearly changes in suicides per district

Table 1 shows the result of a pooled ordinary least squares (POLS) estimation of equation (1). The year of the ICD revision has no significant effect on changes in reported suicide numbers. Therefore, the codings of ICD versions 9 and 10 can be combined into a single measure of suicides.

Age- and Gender-Adjustment of District Suicide Rates

The district specific age- and gender-adjusted standardized suicide rate r_{dt} is given by

$$r_{dt} = 100.000 \sum_{g=0}^{1} \sum_{a=1}^{15} \frac{y_{dta,g}}{p_{dta,g}} \frac{p^e_{a,g}}{\sum_{g=0}^{1} \sum_{a=1}^{15} p^e_{a,g}} \tag{2}$$

d, t, a and g refer to district, time, age and gender-stratum, y is the number of suicides, p and p^e are the raw and European standard populations. Age-strata were generated by grouping all ages < 10 years, 5 age years consecutively > 10 years and all ages > 75 years, resulting in 15 age groups.

Alternate Model Specifications

Basic Fixed Effects (FE) Model

Table 2 below reports the results of a Fixed Effects (FE) estimation of equation (3) in the original publication without a spatial error term. Wald tests were conducted in order to asses the joint significance of variable groups. As it is shown, only the SI variables Moved last year, Single and One-Person-Household were not jointly significant. Since these represent the main interest variables, however, it was decided to keep these in the model. The FE model yields effects sizes comparable to the Spatial Error Model (SEM) estimates presented in the original publication. In contrast to the SEM specification, effects of singles' incomes on suicide rates are significant at $\alpha = 0.1$ while the general income effect is not significant ($p < 0.154$).

	FE - ln Suicide Rate % - Change [95% - CI]	p-value
***SES I* - $F_{Wald}\,(df\ 389) = 3.31; p > F_{Wald} = 0.02$**		
ISEI	0.00 [-0.96, 0.97]	(1.000)
CASMIN	**1.24 [0.37, 2.11]**	**(0.000)**
Income	-0.3 [-0.65, 0.05]	(0.154)
***SES II* - $F_{Wald}\,(df\ 389) = 3.38; p > F_{Wald} = 0.01$**		
Minor Employment	-0.29 [-1.26, 0.69]	(1.000)
Unemployed	**1.59 [0.45, 2.74]**	**(0.000)**
No. Public Transfers	6.35 [-23.72, 48.27]	(1.000)
ALG I/II	-0.11 [-0.96, 0.75]	(1.000)
***SI* - $F_{Wald}\,(df\ 389) = 1.94; p > F_{Wald} = 0.12$**		
Moved last Year	**-1.39 [-2.75, -0.01]**	**(0.048)**
Single	0.19 [-0.68, 1.07]	(1.000)
One-Person-Household	**1.58 [0.04, 3.13]**	**(0.042)**
***SES* × *SI Interactions* - $F_{Wald}\,(df\ 389) = 2.73; p > F_{Wald} = 0.004$**		
ISEI (inv.) × Single	0.34 [-0.59, 1.27]	(1.000)
CASMIN (inv.) × Single	-0.71 [-1.87, 0.46]	(0.846)
Income (inv.) × Single	0.62 [0.1, 1.14]	(0.09)
ISEI (inv.) × One-Person-Household	-0.69 [-1.83, 0.47]	(0.882)
CASMIN (inv.) × One-Person-Household	-0.33 [-1.98, 1.34]	(1.000)
Income (inv.) × One-Person-Household	**-1.19 [-1.97, -0.41]**	**(0.000)**
ISEI (inv.) × Moved last Year	-0.9 [-2.94, 1.19]	(1.000)
CASMIN (inv.) × Moved last Year	**2.93 [0.73, 5.19]**	**(0.000)**
Income (inv.) × Moved last Year	0.25 [-0.49, 0.99]	(1.000)
Observations	5266	
AIC	1228.3	

Notes: The table reports percentage changes of r_{dt} with Bonferroni corrected 95% confidence intervals in square brackets and Bonferroni corrected p-values in parentheses. Control variables are not shown. Results significant at $\alpha = 0.05$ are printed in **bold**. The results of Wald joint significance tests are indicated above the corresponding variable groups."inv." is abbreviated from inverted.
Source: German Microcensus & Death Record, 1997 to 2010, & 2013 European Standard Population - ed. by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

Table 2: FE Regressions of *ln* District Suicide Rates on SES and SI

Corrected Least Square Dummy Variables (LSDVC) Model

The observation year provided, fixed effects and spatial error models allow for the estimation of contemporary SES and SI effects, only. In order to assess the impact of past SES and SI levels on current suicide rates, a model including lagged values of X_{idt} needs to be specified. A parsimonious method in this regard is the Koyck model (1954). Accordingly, we firstly assume that all effects of SES and SI on suicide decline by the same constant rate $|\lambda| < 1$ over time. This is reflected in any of the corresponding model's coefficients with lag length s such that $\beta_s = \beta_0 \lambda^s$. The Koyck method has the advantage that arbitrary choices of lag length are avoided because it allows for an infinite number of lags: Using Prentice and Sheppard's approach (1995) and adding lagged values of the independent variables, let[3]

$$ln(r_{dt}) = n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} f(\mu_d + \sum_{s=0}^{\infty} \beta_s X_{idt-s}) + \delta_{dt}, \tag{3}$$

with a district baseline probability μ_d, an idiosyncratic error δ_{dt} and an identity function $f(\cdot)$. The long run accumulated effect of SES and SI levels on suicide rates $\beta^* = \sum_{s=0}^{\infty} \partial ln(r_{dt}) / \partial X_{idt-s} = \sum_{s=0}^{\infty} \beta_s$ can be obtained after applying the following transformation to (3): Firstly, see that if (3) is true at time t, it is also true at $t-1$:

$$ln(r_{dt-1}) = n_{dt-1}^{-1} \cdot \sum_{i=1}^{n_{dt-1}} f(\mu_d + \sum_{s=0}^{\infty} \beta_{s-1} X_{idt-s-1}) + \delta_{dt-s-1} \tag{4}$$

Then multiply (4) by λ,

$$\lambda ln(r_{dt-1}) = n_{dt-1}^{-1} \cdot \sum_{i=1}^{n_{dt-1}} f(\lambda\mu_d + \sum_{s=0}^{\infty} \lambda\beta_{s-1} X_{idt-s-1}) + \lambda\delta_{dt-s-1}, \tag{5}$$

and subtract (5) from (3). Subsequent rearranging yields:

$$ln(r_{dt}) = \lambda ln(r_{dt-1}) + n_{dt}^{-1} \cdot \sum_{i=1}^{n_{dt}} f(\pi_d + \beta_0 X_{idt}) + \nu_t + \epsilon_{dt}, \tag{6}$$

where $\pi_d = \mu_d - \lambda\mu_d$ and $\epsilon_{dt} = \delta_{dt} - \lambda\delta_{dt-1}$. For the reasons stated in the main article there are also fixed effects π_d and ν_t included. Note now that β^* entails a geometric series that converges to $\beta_0 / 1 - \lambda$. By this means, the long run estimate $\hat{\beta}^*$ can be calculated from the estimated coefficients $\hat{\beta}_0$ and $\hat{\lambda}$. Estimating long run effects, it needs to be considered that $\hat{\beta}^*$ does not provide any information on how long suicide rates take to adjust to changes in X_{idt-s}. In fact, the impact

[3] Please refer to the original publication for an explanation of all the variables included in the equations.

of past values of X_{idt} on suicides decreases with the adjustment rate of the model, that is past levels of SES and SI contribute only little to β^* at high adjustment speeds. In order to assess the average model adjustment time, the mean lag is computed. This is given by $\sum_{s=0}^{\infty} \partial\beta_s/\partial\lambda/\beta^* = \sum_{s=0}^{\infty} s\beta_s/\beta^* = \lambda/1-\lambda$, see also Koyck (1954).

(6) is being estimated by firstly differencing out the fixed effects. As a result of applying this method it should be pointed out that the error term of the demeaned equation will be correlated with its lagged dependent variable regressor (Nickell 1981). The resulting bias is shown to decrease with an increasing time dimension of the panel as $N \to \infty$. Concerning the data utilized for this study, Monte Carlo simulations (Judson & Owen 1999) suggest that $T = 14$ time periods are to few in order to ignore the bias. Applying the standard FE estimator would therefore turn out inconsistent results. Thus, the Corrected Least Square Dummy Variable (LSDVC) estimator derived by Kiviet (1995) and Bun and Kiviet (2003) is applied to estimate (6).[4]

As can be seen from tables 3 and 4, the LSDVC model yields effects sizes comparable to the SEM estimates presented in the original publication. The contemporary and long run effects of income on district suicide rates are significant at $\alpha = 0.1$, as opposed to the SEM specification, which turns out an income effect significant at $\alpha = 0.05$.

[4]FE and an OLS regression with district and time dummies are mathematically equivalent.

	LSDVC - ln Suicide Rate % - Change [95% - CI]	p-value
SES		
ISEI	-0.08 [-1.1, 0.96]	(1.000)
CASMIN	**1.3 [0.38, 2.23]**	**(0.000)**
Income	-0.34 [-0.71, 0.02]	(0.07)
Minor Employment	-0.31 [-1.27, 0.66]	(1.000)
Unemployed	**1.55 [0.38, 2.74]**	**(0.000)**
No. Public Transfers	2.43 [-27.84, 45.38]	(1.000)
ALG I/II	-0.07 [-0.98, 0.86]	(1.000)
SI		
Moved last Year	**-1.45 [-2.85, -0.03]**	**(0.042)**
Single	0.35 [-0.54, 1.24]	(1.000)
One-Person-Household	1.49 [-0.16, 3.18]	(0.093)
SES* × *SI Interactions		
ISEI (inv.) × Single	0.32 [-0.64, 1.29]	(1.000)
CASMIN (inv.) × Single	-0.77 [-2.01, 0.48]	(0.702)
Income (inv.) × Single	**0.55 [0.00, 1.09]**	**(0.045)**
ISEI (inv.) × One-Person-Household	-0.83 [-2.04, 0.4]	(0.558)
CASMIN (inv.) × One-Person-Household	-0.43 [-2.18, 1.35]	(1.000)
Income (inv.) × One-Person-Household	**-1.042 [-1.88, -0.2]**	**(0.009)**
ISEI (inv.) × Moved last Year	-0.920 [-3.17, 1.39]	(1.000)
CASMIN (inv.) × Moved last Year	**3.33 [0.97, 5.75]**	**(0.000)**
Income (inv.) × Moved last Year	0.0550 [-0.74, 0.85]	(1.000)
ln Suicide Rate - 1st lag	**0.09 [0.06, 0.12]**	**(0.000)**
Observations	4970	
AIC	1139.2	

Notes: The table reports percentage changes of r_{dt} with Bonferroni corrected 95% confidence intervals in square brackets and Bonferroni corrected p-values in parentheses. Control variables are not shown. Results significant at $\alpha = 0.05$ are printed in **bold**."inv." is abbreviated from inverted.
Source: German Microcensus & Death Record, 1997 to 2010, & 2013 European Standard Population - ed. by the German Federal Statistical Office (DESTATIS), own calculations were performed with STATA 15.0.

Table 3: LSDVC Regressions of *ln* District Suicide Rates on SES and SI

Long Run Effects	LSDVC - ln Suicide Rate % - Change [95% - CI]	p-value
SES		
$\hat{\beta}^*_{ISEI}$	-0.08 [-1.21, -0.08]	(1.000)
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{CASMIN}}$	**1.43 [0.42, 2.45]**	**(0.000)**
$\hat{\beta}^*_{Income}$	-0.34 [-0.78, 0.02]	(0.07)
$\hat{\beta}^*_{Minor\ Employment}$	-0.34 [-1.39, 0.73]	(1.000)
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{Unemployed}}$	**1.7 [0.41, 3.02]**	**(0.000)**
$\hat{\beta}^*_{No.\ Public\ Transfers}$	2.67 [-30.15, 50.92]	(1.000)
$\hat{\beta}^*_{ALG\ I/II}$	-0.07 [-1.08, 0.94]	(1.000)
SI		
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{Moved\ last\ Year}}$	**-1.59 [-3.13, -0.04]**	**(0.042)**
$\hat{\beta}^*_{Single}$	0.38 [-0.6, 1.37]	(1.000)
$\hat{\beta}^*_{One-Person-Household}$	1.64 [-0.18, 3.49]	(0.093)
SES × SI Interactions		
$\hat{\beta}^*_{ISEI\ (inv.) \times Single}$	0.35 [-0.71, 1.42]	(1.000)
$\hat{\beta}^*_{CASMIN\ (inv.) \times Single}$	-0.85 [-2.21, 0.53]	(0.702)
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{Income\ (inv.) \times Single}}$	**0.6 [0.00, 1.2]**	**(0.045)**
$\hat{\beta}^*_{ISEI\ (inv.) \times One-Person-Household}$	-0.91 [-2.24, 0.45]	(0.558)
$\hat{\beta}^*_{CASMIN\ (inv.) \times One-Person-Household}$	-0.48 [-2.39, 1.48]	(1.000)
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{Income\ (inv.) \times One-Person-Household}}$	**-1.04 [-2.07, -0.22]**	**(0.009)**
$\hat{\beta}^*_{ISEI\ (inv.) \times Moved\ last\ Year}$	-1.01 [-3.49, 1.53]	(1.000)
$\hat{\boldsymbol{\beta}}^*_{\boldsymbol{CASMIN\ (inv.) \times Moved\ last\ Year}}$	**3.67 [1.06, 6.36]**	**(0.000)**
$\hat{\beta}^*_{Income\ (inv.) \times Moved\ last\ Year}$	0.06 [-0.81, 0.93]	(1.000)
Mean Lag Time		
$\hat{\boldsymbol{\lambda}}^*$	**0.1 [0.06, 0.13]**	**(0.000)**

Notes: The table reports percentage changes of r_{dt} with Bonferroni corrected 95% confidence intervals in square brackets, except for $\hat{\lambda}^*$ where it presents the mean lag time in years. Bonferroni corrected p-values are shown in parentheses. Results significant at $\alpha = 0.05$ are printed in **bold**. The CI are based on delta method approximated S.E.. "inv." is abbreviated from inverted. *Source:* German Microcensus & Death Record, Area Population Numbers of Germany, 1997 to 2010, & 2013 European Standard Population - ed. by the German federal statistical office (DESTATIS), own calculations were performed with STATA 15.0.

Table 4: LSDVC Regressions of *ln* District Suicide Rates on SES and SI - Long Run Effects

Anlagen

Erklärung über die eigenständige Abfassung der Arbeit

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig und ohne unzulässige Hilfe oder Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Ich versichere, dass Dritte von mir weder unmittelbar noch mittelbar eine Vergütung oder geldwerte Leistungen für Arbeiten erhalten haben, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen, und dass die vorgelegte Arbeit weder im Inland noch im Ausland in gleicher oder ähnlicher Form einer anderen Prüfungsbehörde zum Zweck einer Promotion oder eines anderen Prüfungsverfahrens vorgelegt wurde. Alles aus anderen Quellen und von anderen Personen übernommene Material, das in der Arbeit verwendet wurde oder auf das direkt Bezug genommen wird, wurde als solches kenntlich gemacht. Insbesondere wurden alle Personen genannt, die direkt an der Entstehung der vorliegenden Arbeit beteiligt waren. Die aktuellen gesetzlichen Vorgaben in Bezug auf die Zulassung der klinischen Studien, die Bestimmungen des Tierschutzgesetzes, die Bestimmungen des Gentechnikgesetzes und die allgemeinen Datenschutzbestimmungen wurden eingehalten. Ich versichere, dass ich die Regelungen der Satzung der Universität Leipzig zur Sicherung guter wissenschaftlicher Praxis kenne und eingehalten habe.

....

Ort, Datum Anatol-Fiete Näher

Berlin, den 12.02.2020

Spezifizierung des eigenen wissenschaftlichen Beitrags

Hiermit bestätigen wir, dass Anatol-Fiete Näher den maßgeblichen Anteil an der Publikation

Näher, A. F., Rummel-Kluge, C., & Hegerl, U. (2020). Associations of Suicide Rates with Socioeconomic Status and Social Isolation: Findings from Longitudinal Register and Census Data. *Frontiers in Psychiatry, 10*, 898. doi: 10.3389/fpsyt.2019.00898

innehat. Die Beiträge bestehen in:

- der Recherche bereits bestehender Forschungsliteratur
- der Ableitung der Rationale der Studie und der Formulierung entsprechender Hypothesen
- der Ausarbeitung des Antrags zur Nutzung der vom statistischen Bundesamt zur Verfügung gestellten Register- und Zensusdaten
- der Erarbeitung des Studiendesigns, inkl. der Operationalisierung von Messkonzepten zur Erfassung sozioökonomischer Merkmale sowie der Entwicklung statistischer Modelle auf Grundlage bestehender biostatistischer und ökonometrischer Literatur
- der Implementation der statistischen Modelle und dem Verfassen des entsprechenden Programmcodes in STATA 15.0 (ca. 25 Seiten)
- der Aufbereitung der Rohdaten, inkl. der Umcodierung derselben zur Umsetzung o.g. Messkonzepte
- der Datenanalyse
- der Interpretation und Einordnung der Ergebnisse
- dem Verfassen des Manuskripts
- der Anpassung des Manuskripts an die Review-Kommentare sowie die Durchführung der im Verlauf des Review-Prozesses geforderten Reanalyse der Daten

C. Rummel-Kluge

Prof. Dr. med. C. Rummel-Kluge

Prof. Dr. med. U. Hegerl

Universitätsklinikum Leipzig
Department für Psychische Gesundheit
Klinik und Poliklinik für Psychiatrie und Psychotherapie
Prof. Dr. med. Christine Rummel-Kluge
Leiterin der Psychiatrischen Institutsambulanz
Semmelweisstr. 10, Haus 10 · 04103 Leipzig
Telefon 0341 / 97-2 43 04

Danksagung

Ich bedanke mich ausdrücklich bei meinen Betreuern Prof. Dr. med. Christine Rummel-Kluge und Prof. Dr. med. Ulrich Hegerl und außerdem bei Prof. Dr. med Georg Schomerus für die Offenheit, sich des Themas der Dissertation anzunehmen und für die finanzielle Unterstützung sowie engagierte Beratung bei deren Realisation. Danken möchte ich ebenso den Mitarbeiterinnen und Mitarbeitern des Berliner Forschungsdatenzentrums des statistischen Amtes der Länder für ihren außerordentlichen Einsatz bei der Datennutzung. Darüber hinaus gilt mein Dank Bernhard Boockmann für stetige Inspiration und Motivation. Stephan Poppe gebührt mein Dank für Anregung und Kritik und Dave Scharf dafür, mir zu zeigen, wie sich so manches vereinfachen lässt. Das wenigste wäre möglich gewesen ohne die Toleranz, Geduld und Unterstützung meiner Familie, der ich hiermit meinen ganz besonderen Dank bekunde.

Aus Gründen des Schutzes persönlicher Daten ist der Lebenslauf in dieser Online-Version der Arbeit nicht enthalten.