

博士論文

The impact of rural context on suicide mortality and its potential
mechanisms: A Swedish registry-based multilevel cohort study
focusing on country of birth

(農村に住むことが自殺に与える影響とそのメカニズムの検
討：出身国に着目したスウェーデンのレジストリ・データ
を用いた縦断研究)

金森 万里子

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縦断研究)

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Abstract

Some countries have high suicide rates in rural areas. In Sweden, where immigration has been increasing, dispersion policies have directed refugees/migrants to settle in rural areas. Contextual factors varying by residence in rural or urban areas may have different effects on the suicide of residents by nativity. This dissertation aimed to elucidate urban-rural differences in suicide in Sweden from three perspectives: the country of birth of the residents, the areal unit used to evaluate rurality, and the link to sociodemographic factors. We conducted a registry-based cohort study covering the total Swedish adult population from 1991 to 2016. Our three-level (individuals, neighborhoods, and municipalities) regression analyses showed that men in rural municipalities/neighborhoods had a higher suicide risk than those in urban areas regardless of country of birth, with a potentially stronger impact of residing in rural areas among foreign-born men. When evaluating rurality at the municipality level, we observed an increased suicide risk from living in rural municipalities among men born in European countries, including native Swedes. When evaluating rurality at the neighborhood level (the smaller areal units within municipalities), rurality was associated with an increased suicide risk in men for all country of birth groups, especially for those born in non-European countries. Individual sociodemographic characteristics explained the excess suicide risk in rural municipalities, but not the excess risk in rural neighborhoods. Public health policy should focus on individuals' access to resources in rural municipalities and income distribution and other community characteristics in smaller communities within municipalities to accomplish equitable health.

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I was fortunate to meet my partner, Yura K. Ko. During the COVID-19 pandemic, his presence was a source of great support for me while I was writing this dissertation. He also provided technical advice concerning the figures.

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Some of the results of this dissertation have been published below.

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2. Mariko Kanamori, Naoki Kondo, Sol P. Juárez, Agneta Cederström, Andrew Stickley, Mikael Rostila. Does increased migration affect the rural–urban divide in suicide? A register-based repeated cohort study in Sweden from 1991 to 2015. *Population, Space and Place*. e2503, 2021.

Ethical approval

The SMASH project received formal approval from the Regional Ethical Review Board of Stockholm in 2014 (decision number: 2017/716-31/5). We also obtained formal approval from the Ethics Review Board of the Graduate School of Medicine and Faculty of Medicine at the University of Tokyo (2019119NI).

Competing Interests

None

Preface

The basis of this research stemmed initially from my awareness of suicide issues. When I was working as a cattle veterinarian in Hokkaido, in the northern part of Japan, I often heard about people who had died by suicide. Health is related to age, genetics, sex, and lifestyle, but it is also influenced by social structures such as the living environment, socio-economic status, and social relationships. Social inequalities between urban and rural areas can lead to health inequalities. I believe it is important for a sustainable society to describe and address these inequalities.

Various social contexts are intersectionally related. This dissertation challenged me to address multiple topics simultaneously, including suicide, urban-rural social inequality, and immigration. I wrote it with the hope that it would present a perspective that could relate to a disadvantaged existence in various contexts.

While conducting my research, I collaborated with the SMASH project team at Stockholm University, Sweden. I visited Sweden in 2019 to conduct the analysis. I had to cancel further travel due to the occurrence of the COVID-19 pandemic, but I look forward to revisiting Sweden. I hope this research will contribute something to the people in Sweden and people living in rural areas in Japan and elsewhere.

Mariko Kanamori

Tokyo, January 12, 2022

1. Introduction

1.1. Global trends in suicide mortality by rurality

Suicide is an important public health issue worldwide. The World Health Organization has estimated that approximately 703,000 people across the world kill themselves every year [1]. There are regional variations in suicide mortality, and various countries have reported that rural areas have higher suicide rates than urban areas [2–5] (Table 1). Many reports on suicide rates by rurality have come from Australia [6–8] and the United States [9,10], as well as European countries [11–15]. Reports from other countries at various income levels, including Canada [16], China [17,18], India [19], Japan [20,21], New Zealand [22], South Korea [23], and Taiwan [24] have also showed high suicide rates in rural areas. In the Nordic countries, the county-level regional distribution of suicide mortality showed that the rates in the capital regions of Copenhagen, Oslo, and Stockholm were lower than the national suicide rate in Denmark, Norway, and Sweden, respectively [25].

Across these earlier studies, the definition of rural areas has varied, as have the geographical units used to evaluate rurality, ranging from county level to postal code. There is no universal agreement about how rurality [26], which can consist of multiple geographical, political, and cultural dimensions [27], should be defined. Therefore, defining rurality according to the specific purpose of the study has been recommended [28]. Comparing multiple indicators, Helbich et al. found that population density and accessibility to other people in the community (e.g., the number of people that can be reached within a certain travel time) were efficacious in identifying the relationship between rurality and suicide [13]. Indeed, numerous studies that have examined the association between rurality and suicide have used indicators with a component of population size or population concentration when defining rurality.

Table 1. Suicide indicators in urban and rural areas: an overview of previous studies.

Author	Country	Year	Category of rurality	Areal unit of rurality	Indicator	Male suicide indicator		Female suicide indicator	
						Urban	Rural	Urban	Rural
Cheung et al. [6]	Australia	2004-2008	Rural, Remote, Metropolitan	Postal area	Age-standardized suicide rates per 100,000 person-years	Metropolitan zones: 15.67	Rural zones: 18.19; Remote zones: 30.00	Metropolitan zones: 4.60	Rural zones: 4.56; Remote zones: 5.54
Qi et al. [7]	Australia	2005*	Capital cities, regional centers, rural/remote areas	Local government area	Suicide rates per 100,000 population	Capital cities: 15.0**; Regional centers: 16.0**	Rural/remote areas: 21.0**	Capital cities: 4.0** Regional centers: 4.3	Rural/remote areas: 4.5**
Caldwell et al. [8]	Australia	1997-2000	Metropolitan, rural centers, other rural/remote areas	Local statistical areas	Suicide rates per 100,000 population	Metropolitan areas: 20.2	Rural centers: 24.0; Other rural/remote areas: 25.7	Metropolitan areas: 5.6	Rural centers: 5.7; Other rural/remote areas: 5.1
Singh & Siahpush [9]	United States	1995-1997*	10-category continuum measure	County	Age-adjusted suicide rates per 100,000 population	Most urban: 17.45	Most rural: 26.88	Most urban: 4.05	Most rural: 4.01
Ivey-Stephenson et al. [10]	United States	2013-2015*	Large metropolitan, medium/small metropolitan, nonmetropolitan/rural	County	Age-adjusted suicide rates per 100,000 population	Large metropolitan: 20.20	Nonmetropolitan/rural: 31.62	Large metropolitan: 5.91	Nonmetropolitan/rural: 8.06
Kapusta et al. [11]	Austria	1995-2005*	Five categories of rurality	District	Suicide rates per 100,000 population	Most urban: 26.3	Most rural: 37.8	Most urban: 11.8	Most rural: 10.5
Razvodovsky & Stickley [12]	Belarus	2005*	Urban, rural	Region	Age-standardized suicide rates per 100,000 population	Urban: 38.79	Rural: 94.73	Urban: 6.78	Rural: 11.67

Levin and Leyland [14]	Scotland	1995-1999*	Four categories of rurality	Postcode sector	Standardized suicide ratios	Urban: 102	Accessible rural: 91; Remote town: 118; Remote rural: 136	Urban: 110	Accessible rural: 83; Remote town: 109; Remote rural: 94
Zacharakis et al. [15]	Greece	1991*	Urban, semi-urban, rural	-	Age-standardized suicide rates per 100,000 population	Urban: 4.08	Rural: 8.7	Urban: 1.06	Rural: 2.8
Ostry [16]	Canada	1986-1996	Seven metropolitan influenced zones	Census sub-division	Suicide rates per 100,000 population	Urban: 19.3	Remote: 38.4	Urban: 5.7	Remote: 7.9
Yip et al. [17]	China	2000*	Urban, rural	-	Suicide rates per 100,000 population	Urban: 6.0	Rural: 21.0	Urban: 6.1**	Rural: 22.0**
Patel et al. [19]	India	2010	Urban, rural	-	Age-standardized suicide rates per 100,000 population	Urban: 14.4	Rural: 31.5	Urban: 12.0	Rural: 20.4
Yoshioka et al. [21]	Japan	2009-2017	Ten deciles of rurality	Municipality	Rate ratios of suicide	Most urban: ref.	Most rural: 1.33	Most urban: ref.	Most rural: 1.08
Pearce et al. [22]	New Zealand	1999-2001*	Urban, rural	Census area unit	Age-standardized suicide rates per 100,000 population	Urban: 19.5**	Rural: 21.5**	Urban: 5.6**	Rural: 5.1**

Note: Studies that provided suicide indicators by rurality/urbanicity and gender were included in the table. Studies that were limited to a specific age group were not included in the table.

*Although results from other years are available, only the most recent results are included in the table.

** Values were visually obtained from the figure in the paper.

Since the social environment reflected by rurality changes over time, research has been undertaken on the secular trends in suicide rates between urban and rural areas in several countries. For the period from the 1960s to the 2000s, among men, even though suicide rates had been higher in urban than rural areas in some countries in earlier periods, many countries experienced greater increases in rural areas [12,15,29–32]. Among women, studies have reported higher rates in urban than in rural areas, but in some instances, urban figures improved while rural figures did not change or even increased [9,22,29]. Thus, the geographic distribution of suicide rates may have changed disproportionately over time between urban and rural areas. However, according to a recent systematic review of studies conducted in four English-speaking high-income countries [2], information on the current situation is lacking among the countries reviewed (i.e., Australia, Canada, the United Kingdom, and the United States). More recently after the 2000s, the increase observed in suicide rates in both genders in the United States was steeper in rural than in urban areas during 2001 to 2015, which suggests that there may be an increased vulnerability for mental health problems of residing in rural areas [10].

While urban-rural differences in suicide mortality have been reported in many countries, there is limited research on the underlying mechanisms. For example, Morrell et al. showed that the suicide incidence of men residing in rural areas was higher than those in urban areas in New South Wales in Australia, which may have mostly been due to excess suicide among migrants [33]. Therefore, although many studies have used aggregated data at the regional level, it may be valuable to investigate the multilevel association between regional rurality and individual suicide incidence, considering that individual characteristics including country of birth, as well as regional characteristics other than rurality have been linked to suicide mortality as we discuss in the next section.

1.2. Conceptual framework for understanding regional variations in suicide

Suicide is related to factors that occur at an individual-level through to contextual and place characteristics at the community level and other factors associated with more macroscopic social levels [34,35]. The social characteristics of regions and societies, such as macroeconomic fluctuations, socioeconomic disadvantage at the local level, the built environment, social capital, policies, and culture, can all affect individual health [36–40].

To understand geographical variations in health outcomes, Macintyre and colleagues organized a framework for understanding the “place effect” on health, which consists of compositional, contextual, and collective explanations [41]. They stated that “compositional explanations draw our attention to the characteristics of individuals concentrated in particular places; contextual explanations draw our attention to opportunity structures in the local physical and social environment; collective explanations draw our attention to socio-cultural and historical features of communities.” [41]. Judd et al. (2006) subsequently applied this framework while examining the potential reasons for the high suicide rate in rural areas in Australia [42]. Based on its use by Judd et al., I have reorganized the table of possible explanations for geographic variations in suicide (Figure 1). Several factors that recent reviews of the relationship between rurality and suicide [2–5] and our previous research [43,44] have indicated may be of relevance are added. Collective explanations are positioned as part of contextual explanations because collective features are part of the context shared by people living in a specific place [41]. For example, suppose that one study found high suicide rates in agricultural areas and farmers were an occupational group with high suicide rates [45]. These results can be explained in different ways based on compositional and contextual perspectives. A compositional explanation might be that suicide is high in agricultural areas because farmers take their own lives more often than other workers. On the other hand, contextual explanations, focusing on the materialistic and psychosocial features of a region,

may highlight that agricultural communities suffer from difficulties relating to socioeconomic disadvantage, climate change, and gender relations, that lead to strong mental stress on the residents of agricultural areas [46].

Possible explanations for geographic variations in suicide		
Compositional	Contextual	
Psychological and physical health factors	Material	Psychosocial (collective)
Substance abuse	Area-level socioeconomic factors	Gender relations
Socioeconomic status — income, education, employment	Income inequality	Community attitudes to mental illness
Occupation — farmers	Service availability and accessibility	Acceptance of suicide
Race/Ethnicity — migrants, indigenous groups	Agricultural factors — climate change, global competition, exposure to pesticides, farm density, type of agriculture	Stigma and help seeking
Age	Social and geographic isolation	Familiarity with firearms
Sex/Gender	Immigrant density	Social capital
Marital status		Religious beliefs and spiritual views

Figure 1. Possible explanations for geographic variations in suicide (adapted from Judd, F., Cooper, A., Fraser, C., & Davis, J. (2006). Rural suicide — people or place effects? *Australian and New Zealand Journal of Psychiatry*, 40(3), 208–216. <https://doi.org/10.1080/j.1440-1614.2006.01776.x>).

Agricultural activity is one contextual feature of many rural areas. It is well known that structural changes in the agricultural sector, a greater economic burden and geographical and social isolation are risk factors for farmer’s poor mental health [45,47–49]. Focusing on farmer density as a structural aspect of agriculture, together with my colleagues I analyzed its association with the mental health of farmers in Japan and found that the prevalence of farmer’s depressive symptoms was higher in areas where there was a low farm density than in areas with a high density, suggesting that the mental health of farmers might be affected by neighborhood farm density [43]. Moreover, considering that the context of an agricultural community may vary depending on the predominant types of agriculture in an area [50], I and my colleagues previously reported that suicide mortality was positively associated with animal husbandry output per unit of the municipality population, whereas no association was

observed for other forms of agricultural output using Japanese municipal data [44]. Thus, distinguishing between compositional and contextual explanations can be useful in understanding regional differences in suicide mortality.

In the current study, we focused on sociodemographic factors that can have both a contextual and compositional risk for suicide, namely, socioeconomic status, including education history, employment status, and income; as well as immigrant status, which have long been studied as key social determinants of health [51]. There is a gradient in health according to individual socioeconomic status, with socially disadvantaged groups having poorer health in general, with the same also being true for suicide mortality [52–54]. The concentration of vulnerable individuals may explain regional differences in suicide rates (a compositional explanation). In addition, area-level socioeconomic disadvantage, usually measured by the percentage of persons below the poverty line and the percentage of unemployed individuals in an area, can also affect health. According to two recent systematic reviews, area-level socioeconomic disadvantage is associated with high levels of suicide and suicidal behavior, suggesting that social isolation and economic hardship in areas of poverty can lead to suicide (a contextual explanation) [39,40]. Another possible explanation that can link area-level socioeconomic disadvantage and suicide is low community social capital in disadvantaged areas, including the erosion of a sense of mutual trust and norms of reciprocity [55].

The potential health effects of immigrant population density are a relatively new area of research. An earlier systematic review suggested that, for members of ethnic minority groups, living in areas with a high proportion of people of the same ethnicity can have a protective effect on various mental health outcomes [56]. Pan and Carpiano reported that in Canada, the protective effect of immigrant density against suicidal ideation was larger in rural areas than in urban areas, and for non-white immigrants than for white immigrants [57].

Although this ‘ethnic density effect’ has yet to be fully elucidated, theoretically, pathways such as increased social support are thought to be involved. On the other hand, in countries such as Sweden, where immigration has increased rapidly in recent years, ethnic segregation in major cities such as Malmö and Stockholm has been reported as a social problem in the media since the late 2000s [58]. The concentration of immigrants in the more inaccessible areas of the city, has resulted in disparities in access to the center and fewer opportunities for interaction and inclusion [59]. The situation is also different for labor migrants and refugees, with the latter being more vulnerable [59]. The increasing severity of such segregation has been reported to be associated with various forms of social unrest, such as vehicle arson [58].

1.3. Statistical methods to analyze compositional/contextual effects

The potential health effects of living in a rural area are multilayered – social determinants of health across multiple levels can affect an individual’s health [60]. Investigating information with a hierarchical structure, such as individual and region, provides evidence of how different macro-level features of the environment of an area can affect individual health. Analyzing the association between aggregated values (e.g., rurality and the suicide rate) and interpreting the results by applying them at the individual level (e.g., moving to rural areas is a suicide risk) can lead to what has been termed the ‘ecological fallacy’ [61]. By contrast, focusing only on individual-level correlations (e.g., living in a rural area and suicide incidence) may lead to the ‘individualistic fallacy,’ where there is an absence of structural and environmental perspectives underlying individual health outcomes (i.e., ignoring the contextual effect of rural neighborhoods) [62]. Hence, to untangle the mechanisms linking urban-rural residence and suicide, multilevel analyses that can simultaneously model variables at the regional and individual levels are useful [62].

A multilevel model (or mixed model) allows us to take the hierarchical structure of the data, such as individual and region, into account by incorporating the interregional variance into a model as a random effect [63–65]. Using regional- and individual-level variables in a multilevel analysis makes separating the contextual and compositional effects possible. We can also examine the extent to which region-level and individual-level variables explain the variance in health indicators across regions [66]. Moreover, the potential effect of a residential area may not be homogenous across the resident population; that is, the effect of area-level factors can vary by individual characteristics (e.g., country of birth). To clarify this, analyzing a cross-level interaction between a macro-level factor (higher level) and an individual-level factor (lower level) can be useful [67].

When considering the effect of rural residence, it should be noted that there can be a dynamic relationship between individual characteristics and the impact of the contextual features of a residential area [68]. Some authors have argued that individual socioeconomic status should not be considered as a confounding factor since the surrounding environment (i.e., place) can affect individuals' resources and opportunities such as their ability to obtain well-paid jobs and a better education [5,41]. Adjusting for these factors as confounders when analyzing the relationship between rural residence and suicide may underestimate the impact of the collective characteristics of an area on mental health. Therefore, in this study, individual-level socioeconomic status is not treated as a confounder but rather, as a factor that could mediate the effects of the characteristics of a residential place on suicide.

1.4. Urbanization and migration

During the ongoing process of worldwide urbanization, most rural areas have experienced population declines. In 1950, 66 percent of the world's population lived in rural areas, but by

2017 this figure had declined to 45 percent [69]. Fraser et al. (2005) positioned population decline as an indicator of and a contributor to social and economic decline, and found that people who lived in communities where the population was declining tended to have worse mental health outcomes [70]. Population decline in rural areas not only affects well-being adversely by reducing available resources, but it also creates a sense of entrapment among those individuals that remain in rural areas due to the enhanced out-migration of young people and others [42,46]. Thus, we can speculate that these changing population dynamics and the social and cultural changes in rural areas worldwide may link to increasing suicide in rural areas.

Urbanization is also closely related to international migration issues. The number of international migrants has continued to grow rapidly in recent years, reaching 258 million in 2017 [71]. In Sweden, people with a foreign background (those born abroad or having two foreign-born parents) comprised 24.1% of all residents in 2017, and this figure is increasing [72]. The proportion of foreign-born residents has increased dramatically in recent years (from 9.2% in 1990 to 17.0% in 2015), with an especially rapid increase in non-European refugees [73]. To prevent the concentration of immigrants in urban areas, and in order to counter the effects of economic decline and population loss in rural areas, the Swedish Refugee Placement Policy promoted the distribution of newly arrived refugees to rural areas from 1985 to 1994 [74–76]. The government assigned asylum seekers their initial residence municipality, and many were placed in rural municipalities [75]. Since 1994, asylum seekers and refugees have been given the option to arrange their first place of residence by themselves or to be accommodated by the government [77]. Even though these individuals were free to move once their first residence in Sweden had been decided, approximately 80% of refugees who were assigned housing in rural areas settled there for more than eight years; this was the case not only in the 1990s but also in the late 2000s [77]. Rural municipalities have tended to

accept more refugees per capita than urban municipalities since the lower population density entails better housing opportunities [74]. The same processes are also occurring in other countries against a global backdrop of increasing international migration, which has resulted in more migrants being dispersed to rural areas [77,78]. Not only refugees, but international migrants in general, have received attention in the literature for their potential to change the demographic composition of rural areas [79]. Indeed, some countries have taken steps to actually attract international migrants to their rural areas [80].

1.5. Complex pattern of suicide among migrants

As international migration increases, there is a growing interest in the mental health of migrants, especially refugees [81]. This is because although migration can offer positive health benefits, public health research has also found that immigrants are at increased risk for worse mental health due to a variety of factors, including the psychosocial process of loss and change in social ties (family, friends, and the ethnic group), culture, social position, and so on [82,83]. For example, a cohort study in Sweden found that the incidence of schizophrenia and other non-affective psychotic disorders was 2.9 times higher among refugees and 1.7 times higher among other immigrants than among those born in Sweden [84].

Regarding suicide, Forte et al. (2018) suggested that some groups of migrants may have a higher suicide risk, while others have a similar or lower suicide risk when compared to the native population [85]. Studies in Sweden have reported a higher suicide risk in immigrants from Finland and lower risk in immigrants from Southern Europe and the Middle East compared to those who are Swedish-born [86]. The prevalence of depression and anxiety – the primary risk factors for suicide [87] – has also been reported to be higher among immigrants from the Middle East [88] and those born outside Scandinavia [89], compared to

native-born Swedes. Although most immigrants from the Middle East are refugees, the direction of the results is thus seemingly different for mental health disorders and suicide.

Multilevel and multidimensional factors can help explain the complex pattern of suicide risk among immigrants. Specifically, individual behavioral and socioeconomic risks, which are more likely to accumulate in immigrants, can serve as compositional explanations. In contrast, the political, environmental, and cultural contexts of the immigrant's country of birth and their current country of residence can be regarded as contextual explanations. In terms of the latter, a systematic review has suggested that the suicide rate in the birth country of immigrants may be associated with their suicide rate in the destination country [90]. Wider contextual factors in both the migrant's country of birth and destination country potentially affecting individual mental health include accessibility of healthcare and other public services [42], area-level socioeconomic disadvantage [39], social capital [91], gender relations [92], prejudice against specific subpopulations [93], and the religious environment [35]. Moreover, people born in the Middle East also have lower all-cause mortality than native Swedes, and even lower when adjusted for individual socioeconomic status [94,95]. Several cultural factors in the country of birth that can continue to exert an influence after migration, such as a lower tolerance of suicide which is related to religious beliefs [96], and healthy lifestyles that include low levels of alcohol consumption [97], might explain the lower suicide rates of people from the Middle East than those from Sweden. Another possible explanation is the "healthy migrant effect" hypothesis, which states that immigrants may represent a healthier group in their country of origin [98].

1.6. The importance of studying cross-level interaction effects between residence and country of birth

Here, I would like to emphasize that the contextual factors potentially affecting suicide risk also vary across areas *within* the destination country. Specifically, as mentioned previously, rurality is an important factor that can structure these social contexts [42]. For example, rural areas generally have a disadvantage in terms of labor market size and variability. Finding employment in rural areas has been difficult, especially for foreign-born people [76]. Furthermore, ethnic discrimination, stigma, exclusion from the community and social isolation can be common in areas with a lower diversity of ethnic groups and more conservative notions [99–101]. These integration-related difficulties may have had especially detrimental consequences given that both individual sociodemographic characteristics such as unemployment and low income, as well as discrimination are well-known risk factors for suicide [52–54,102,103].

1.7. Measures of rurality at different levels of aggregation

Measures of rurality at different levels of aggregation may reflect different contextual features, and different potential mechanisms might be implicated [40,104,105]. The municipality level, which is the smallest politically independent unit of aggregation in Sweden, and responsible for administering a variety of fields including education, welfare, and employment, may reflect variations in the consequences of urban-rural political decisions [106]. For example, if we hypothesize that rurality affects suicide through the characteristics of the labor market, then a politically meaningful unit of aggregation, such as a municipality, is appropriate for testing this hypothesis as labor market policies are implemented at this level [107]. When

evaluating rurality at smaller units of aggregation, such as neighborhoods or areas within municipalities, an excess suicide risk among particular groups in rural areas might represent interpersonal factors, such as one's social network. Nevertheless, a municipality could include both densely populated and less populated neighborhoods/areas. Measuring rurality only at the municipality level ignores such potential variation. In line with the hypothesis suggesting an elevated suicide risk in rural areas/neighborhoods [42], the contextual effect of rurality on suicide may be more accentuated among those residing in depopulated neighborhoods than among those in populated ones within the same municipality. Moreover, rurality at the municipality level and at a smaller unit level may interact with each other in relation to suicide risk, as the municipality's structural features may exaggerate/buffer the beneficial/detrimental effects of interpersonal relationships and vice versa. Therefore, when studying rurality and suicide risk it is important to consider both levels of aggregation – i.e. municipalities and smaller units (neighborhoods) – and the ways they interact.

1.8. Objective of this dissertation

Chapter 1 has shown that many contextual factors that can change over time may underpin increasing suicide rates in rural areas. However, to date, many of the studies that have investigated regional differences in suicide rates by rurality have had an ecological design, and there have been few studies that have used individual-level data to explore the mechanisms that link rurality to suicide. In particular, no study has focused on differences in geographic units and examined different geographic units simultaneously. In addition, suicide has rarely been studied from the perspective of the dynamics of rural and immigrant populations.

Although suicide is a relatively rare outcome, making it difficult to study using individual-level data, the recent promotion of the Nordic registry database has made it possible to conduct large-scale cohort studies [108]. In connection with this, while undertaking my research I collaborated with the Studies of Migration and Social Determinants of Health (SMASH) project team at Stockholm University, Sweden. In order to provide further evidence about which mechanisms are linked to urban-rural inequalities in suicide mortality, this study had a combined focus on the following three aspects.

- 1) Country of birth: clarifying which countries of birth give rise to greater differences in urban-rural suicide mortality. In order to take into account the heterogeneity of the impact of rural residence due to individual characteristics, we examined the cross-level interaction between rurality and country of birth on suicide. Based on the migrant's background roughly approximated by their country of birth, as manifest in the purpose of migration and susceptibility to discrimination, we will discuss the differences in the results by birth countries.
- 2) Geographical unit: clarifying whether there is a difference in the urban-rural divide in suicide depending on the geographic unit used to evaluate rurality. We use a three-level multilevel model to simultaneously analyze rurality as assessed by two different units. Based on the possible mechanisms suitable for each geographic unit, we will interpret differences in the results by the geographic unit.
- 3) Sociodemographic factors: explore how individual/area-level sociodemographic factors are linked to the association between rurality and suicide, and the extent to which these factors explain the regional variation in suicide. Interpreting the results in combination with the other approaches may provide a better understanding of the mechanisms underlying rural suicide.

This dissertation first reevaluates urban-rural inequalities in suicide, considering the multi-layered nature of the rural environment and the diversity of its dwellers. Specifically, Study 1 aimed to examine the impact of living in rural areas on suicide mortality in Sweden according to country of birth, at two different levels of aggregation. To do this, we designed a cohort study that followed all adults aged 20 years and older from 2011 to 2016, to depict the most recent situation available. We also tested whether the difference in suicide mortality between urban and rural areas could be explained by a higher concentration of socially vulnerable individuals (compositional explanation). Next, in order to better understand the potential mechanisms behind the increase in rural suicide rates in various countries, we focus on the role of increasing international migration. Given the growing population of migrants in Sweden and their dispersion to rural areas, Study 2 aimed to examine whether the increased concentration of migrants could impact the rural–urban divide in suicide and the urban–rural divide across migrant groups. To achieve this, we examined whether trends in suicide mortality vary by country of birth and rurality, by performing a repeated cohort study that assessed place of residence at multiple time points, taking into account newly arrived immigrants and relocation. We also examined how the contextual features of rural areas that can change over time affect the differences in urban-rural suicide rates.

2. Study 1: Does the effect of the rural context vary by country of birth?

2.1. Objectives

In this study, first, we examined whether suicide rates differ by neighborhood- and municipality-level rurality, respectively, and then we determined the contribution at each level to suicide risk. Second, we tested whether the excess risk of living in rural areas is greater for foreign-born individuals than for natives, by examining the effect of a cross-level interaction between country of birth and rurality on suicide risk. Third, we explored whether individual sociodemographic characteristics explain suicide risk by country of birth and rurality. Fourth, we tested whether there is an interaction on suicide risk between municipality-level rurality and neighborhood-level rurality.

2.2. Methods

2.2.1. Data

We used multiple linked Swedish registry data covering the total Swedish population. In Sweden's national registration system, a unique personal identity number makes it possible to link data from different registries to a specific individual. Information was supplied by the Total Population Register (Swedish acronym: RTB) and the longitudinal integration database for health insurance and labor market studies (LISA) from Statistics Sweden, and the cause of death register from the National Board of Health and Welfare. RTB covers residents who stay legally in Sweden for at least one year (or who have a permit to stay for more than one year). It has been estimated that 95% of all immigration and 91% of all emigration is registered within 30 days [109]. The over-coverage of the database has been estimated at between 0.25–0.50% of the registered population, which is mainly due to underreported emigration [109].

LISA includes information on education, income, unemployment, etc., for all individuals aged 16 years or older who are registered as of 31 December in each year [110].

We set the baseline population with information on their residential address in 2011 (n= 9,482,855), and excluded individuals where the data was duplicated (n=159) or who could not be linked to general information such as sex or age (n=3,485). We analyzed people 20 years or older at baseline. Using the data, we designed a cohort study. The baseline year was 2011 and the followed up continued until either a person's suicide, censoring (death occurred from a cause other than suicide, or they moved away from Sweden), or the end of the follow-up in 2016, whichever came first. Within the study cohort, 81,487 men (2.3% of the population) and 64,441 women (1.7%) were lost to follow-up as they left Sweden (as opposed to dying). A total of 3,606,487 men nested within 6,261 neighborhoods in 290 municipalities and 3,696,095 women nested within 6,226 neighborhoods in 290 municipalities met our inclusion criteria. Since some very small Swedish neighborhoods are only populated by men – i.e. the values are missing for women – there are more neighborhoods for men than women (Supplementary Table 1).

2.2.1. Measurements

2.2.1.1. Outcome, age, and country of birth

The outcome is suicide, classified using the ICD codes for intentional self-harm (ICD9: E950-E959; ICD10: X60-X84, Y870). As suicide has different incidence rates by gender and age, we stratified all the analyses by gender and adjusted by age [111], which was categorized in ten-year increments. Country of birth was classified using five categories: (i) Sweden, (ii) other Nordic countries (Denmark, Finland, Norway, and other Nordic countries besides Sweden), (iii) other European countries except the Nordic countries, (iv) Middle Eastern countries (Iraq, Iran, Lebanon, and Syria), and (v) the rest of the world. We categorized these

five categories based on a number of previous studies on country of birth and health in Sweden [95,112,113]. It was also important to separate the large group of Middle Eastern migrants, consisting primarily of refugees, from other categories of foreign-born [81,114]. We included those born in Turkey in the European countries category because their reasons for migration are similar to those of migrants from the European countries [114].

2.2.1.2. Rurality

We used municipality-level and neighborhood-level rurality indicators, and used the municipal classification established by the Swedish Association of Local Authorities and Regions in 2017, found on the Statistics Sweden website [115]. This municipal grouping was done based on the population size, distance from populated areas and commuting patterns. This municipal classification contains three main groups, A, B, and C: A includes 46 large cities and municipalities near large cities, which we defined as “urban”; B includes 108 medium-sized towns and municipalities near medium-sized towns, which we defined as “sub-urban”; and C includes 136 smaller towns/urban areas and rural municipalities, which we defined as “rural.”

Our definition of neighborhood was based on the Demographic Statistical Area (DeSO) area-level measure, developed by Statistics Sweden [116]. It refers to demographic statistical areas established by the government to geographically subdivide the country, in order to monitor the occurrence and degree of segregation and socio-economic conditions in small geographic areas within municipalities [117]. Specifically, there are 5,984 DeSO areas with approximately 700-2,700 inhabitants each. These areas try to respect geographic boundaries such as streets, rivers, and railways. The rurality of each unit is classified as one of the three categories A, B or C, or “other.” A includes areas largely outside major population concentrations or urban areas, which we defined as “rural.” B includes areas largely in a

population concentration or urban areas, but not central in the municipality, which we defined as “sub-urban.” C includes areas located centrally in the municipality, which we defined as “urban.” The geographic distribution of the A, B, and C categories within a municipality or county is available on the information panel of Statistics Sweden [118]. In the DeSO criteria, the remaining residents whose addresses were not classified to other DeSO areas are coded as other, and we treated them as missing. It should be noted that we included those who were missing as a dummy variable in the analysis because it is possible that vulnerable individuals such as the homelessness could be included in this group. Using these data cross-level interactions analyses were undertaken with the aim of additionally uncovering some of the complex contextual-level dynamics between rurality and suicide risk. These analyses can explore, for example, whether suicide risk is influenced by residing in a rural neighborhood within a densely populated urban municipality, i.e. whether the surrounding municipality context matters.

2.2.1.3. Sociodemographic characteristics

We used individual sociodemographic characteristics – marital status (divorced, partner, single, and widowed), education (primary, secondary, tertiary, and unknown), employment status (employed and unemployed), and individual disposable income quintile (highest, high, middle, low, and lowest) – all of which were observed at baseline.

2.2.2. Statistical analysis

We calculated Incidence Rate Ratios (IRRs) using three-level (individual, neighborhood, and municipality) Poisson regression analysis, stratified by gender. Although survival analysis is frequently used in epidemiologic studies, we used the Poisson model, for which the validity of Median Rate Ratios (MRRs) and estimated general contextual effects using three-level data

was available, as described below. We were not able to find any validated methods for calculating MRRs using three-level survival models. We used the *mepoisson* command in STATA/MP 15.1 and incorporated random intercepts at the neighborhood level and the municipality level (StataCorp, LLC, College Station, Texas, USA). The offset variable was the logarithm of person-years. We created dummy variables for the missing data in the covariates and modelled them. We first analyzed a null (empty) model to evaluate the variance of the random parameters, and then added variables in the following order: age (Model 1), country of birth (Model 2), municipality-level rurality (Model 3) or neighborhood-level rurality (Model 4), and both neighborhood- and municipality-level rurality to examine the independent contributions of rurality, evaluated at two different levels of aggregation, to suicide (Model 5). To interpret the magnitude of the effects of clustering at the municipal or neighborhood level, we calculated MRRs from the estimated variance of the random parameters, which means the median relative change in the incidence rate of suicide when comparing a randomly selected resident from a group with a higher suicide rate and one from another with a lower suicide rate [119]. Comparing MRRs calculated from each model with the fixed effect of the different levels of rurality, we evaluated the magnitude of the effects of rurality. Then, to assess whether differences in suicide rates by rurality varied by country of birth, we tested a cross-level interaction term between rurality and country of birth. To evaluate the urban-rural gap in the estimated suicide rate by country of birth, we calculated Pair Ratios of rural areas (reference: urban areas) by country of birth, using the Health Disparities Calculator version 2.0.0 [120]. The Pair Ratio in suicide between urban and rural areas is the simple arithmetic ratio (Health Disparities Calculator). Next, to assess how the effect of neighborhood-level rurality differed from municipality-level rurality, we tested an interaction term between municipality-level rurality and neighborhood-level rurality, adjusted for age and country of birth. We also described differential suicide incidence by rurality by

age groups, adding a cross-level interaction term between rurality and age groups. Finally, to explore whether individual sociodemographic characteristics explained differential suicide risk across rurality, we added individual sociodemographic characteristics in Model 6 and compared the results with Model 5. We calculated the percent change from Model 5 to Model 6 for the excess risk of suicide among those residing in rural areas compared to those in urban areas.

2.2.3. Sensitivity analysis

We conducted two types of sensitivity analysis, namely for measurement and for the statistical modeling approach. First, since the definition of rural areas is relative and can vary by comparative area, we used the Degree of Urbanization (DEGURBA) measure that has been devised by Eurostat [122] for municipality-level rurality. DEGURBA is a classification measure for European areas that is based on geographical contiguity and a minimum population threshold applied to 1km² population grid cells, using a 2011 population grid and the 2016 local administrative unit boundaries. Densely populated municipalities are classified as “cities,” areas with an intermediate density are classified as “towns and suburbs,” while thinly populated areas regarded as “rural areas.” Second, instead of IRRs, we calculated Hazard Ratios (HR) using a parametric three-level (individual, neighborhood, and municipality) survival model, which assumes a Weibull distribution [123]. We used the *mestreg* command in Stata/MP 15.1 to fit multilevel mixed-effects parametric survival models, assuming normally distributed random effects.

2.3. Results

Among men, descriptive data showed that the suicide incidence rates per 100,000 person-years were higher among those born in other Nordic countries, followed by those born in Sweden, other European countries, Middle Eastern countries, and the rest of the world (Table 2). Compared to urban municipalities or urban neighborhoods, the suicide incidence rates were higher among men residing in rural municipalities and rural neighborhoods. The null model from the multilevel regression analysis showed that the incidence rate varied between municipalities and between neighborhoods: the MRRs were 1.21 and 1.33, respectively (Table 3). In the models with regional and individual fixed-effects estimators, the IRRs were 1.23 (95% confidence intervals [CI]: 1.09 to 1.38) in rural municipalities and 1.18 (95% CI: 1.08 to 1.28) in rural neighborhoods, compared to urban municipalities or urban neighborhoods (Table 3, Model 5). When we added age, country of birth, municipality-level rurality, and neighborhood-level rurality, the MRRs changed slightly (Supplementary Table 5).

Table 2. Descriptive statistics of variables included in the Study 1.

	Men			Women		
	Person-years	No. of suicides	Suicide rate ^a	Person-years	No. of suicides	Suicide rate ^a
Age						
20-29	3,738,938	593	15.9	3,557,891	234	6.6
30-39	3,617,706	489	13.5	3,502,468	209	6.0
40-49	3,929,550	714	18.2	3,820,285	338	8.8
50-59	3,438,223	733	21.3	3,404,766	306	9.0
60-69	3,385,704	619	18.3	3,460,775	269	7.8
≥ 70	2,635,665	663	25.2	3,543,743	256	7.2
Country of birth						
Sweden	17,319,900	3,357	19.4	17,567,923	1,349	7.7
Other Nordic countries	583,639	143	24.5	786,295	73	9.3
Other European countries	1,287,601	173	13.4	1,339,511	108	8.1
Middle Eastern countries	638,352	63	9.9	550,018	18	3.3
Rest of the world	916,294	75	8.2	1,046,181	64	6.1
Municipality-level rurality^b						
Urban	7,275,016	1,174	16.1	7,596,307	622	8.2
Sub-urban	7,962,191	1,481	18.6	8,142,325	582	7.1
Rural	5,508,579	1,156	21.0	5,551,296	408	7.3
Neighborhood-level rurality^c						
Urban	15,267,422	2,637	17.3	16,111,982	1,278	7.9
Sub-urban	1,793,103	313	17.5	1,817,851	101	5.6
Rural	3,637,405	836	23.0	3,343,374	227	6.8
Unknown	47,856	25	52.2	16,721	6	35.9
Marital status						
Partner	9,246,559	1,056	11.4	9,385,103	423	4.5
Divorced	2,244,777	674	30.0	2,934,967	369	12.6
Single	8,769,906	1,907	21.7	7,130,647	677	9.5
Widowed	484,544	174	35.9	1,839,211	143	7.8
Education						
Primary	4,232,504	1,136	26.8	4,025,055	412	10.2
Secondary	9,814,996	1,883	19.2	9,143,062	726	7.9
Tertiary	6,363,391	762	12.0	7,808,608	456	5.8
Unknown	334,895	30	9.0	313,203	18	5.7
Employment status						

Employed	13,551,795	1,785	13.2	11,895,515	598	5.0
Unemployed	7,193,991	2,026	28.2	8,850,271	1,014	11.5
Disposable income quintile						
Highest	6,327,669	643	10.2	2,999,280	123	4.1
High	4,878,809	689	14.1	4,468,996	230	5.1
Middle	3,822,064	796	20.8	5,321,065	367	6.9
Low	3,257,862	1,009	31.0	5,336,596	578	10.8
Lowest	2,459,382	674	27.4	3,163,991	314	9.9
Total	20,745,786	3,811	18.4	21,289,928	1,612	7.6

^a Suicide incidence per 100,000 person-years

^b We used the municipality classification devised by the Swedish Association of Local Authorities and Regions for municipality-level rurality.

^c For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistical areas established by the Swedish government.

Table 3. Suicide Incidence Rate Ratios (IRRs) by gender: the results of a multilevel Poisson regression analysis.

	Men					Women				
	Null	Model 5		Model 6		Null	Model 5		Model 6	
	IRR	IRR	95% CI	IRR	95% CI	IRR	IRR	95% CI	IRR	95% CI
<i>Fixed-effect part of the model</i>										
Country of birth										
Sweden		Ref.		Ref.			Ref.		Ref.	
Other Nordic countries		1.19	[1.00,1.40]	0.98	[0.83,1.16]		1.15	[0.91,1.46]	0.98	[0.78,1.25]
Other European countries		0.72	[0.62,0.84]	0.66	[0.56,0.77]		0.99	[0.81,1.21]	0.82	[0.67,1.00]
Middle Eastern countries		0.55	[0.43,0.71]	0.44	[0.34,0.57]		0.39	[0.25,0.62]	0.29	[0.18,0.47]
Rest of the world		0.47	[0.37,0.59]	0.39	[0.31,0.49]		0.77	[0.59,0.99]	0.57	[0.44,0.74]
Municipality-level rurality^a										
Urban		Ref.		Ref.			Ref.		Ref.	
Sub-urban		1.16	[1.04,1.30]	1.04	[0.94,1.16]		0.94	[0.81,1.10]	0.82	[0.72,0.92]
		<i>% change in excess risk</i>		-75.00			-		-	
Rural		1.23	[1.09,1.38]	1.06	[0.95,1.18]		0.97	[0.83,1.13]	0.83	[0.72,0.95]
		<i>% change in excess risk</i>		-73.91			-		-	
Neighborhood-level rurality^b										
Urban		Ref.		Ref.			Ref.		Ref.	
Sub-urban		0.93	[0.82,1.05]	0.96	[0.85,1.09]		0.70	[0.57,0.86]	0.74	[0.60,0.91]
		<i>% change in excess risk</i>		-			-		-	
Rural		1.18	[1.08,1.28]	1.16	[1.07,1.27]		0.84	[0.72,0.97]	0.91	[0.78,1.06]
		<i>% change in excess risk</i>		-11.11			-		-	

Random-effect part of the model

Between-municipality variance^c

0.038	0.019	0.014	0.023	0.019	0.000
(0.013)	(0.008)	(0.007)	(0.014)	(0.014)	(0.000)

Between-neighborhood variance^c

0.090	0.097	0.046	0.138	0.144	0.096
(0.029)	(0.029)	(0.028)	(0.065)	(0.065)	(0.063)

Median Rate Ratios between municipalities

1.21	1.14	1.12	1.16	1.14	1.00
------	------	------	------	------	------

Median Rate Ratios between neighborhoods

1.33	1.35	1.23	1.43	1.44	1.34
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^a We used the municipality classification devised by the Swedish Association of Local Authorities and Regions for municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistical areas established by the Swedish government.

^c Standard error in parentheses.

Model 5: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 6: age, country of birth, municipality-level rurality, neighborhood-level rurality, marital status, education, employment status, disposable income quintile

Full results including the IRRs of the covariates are shown in the supplemental materials.

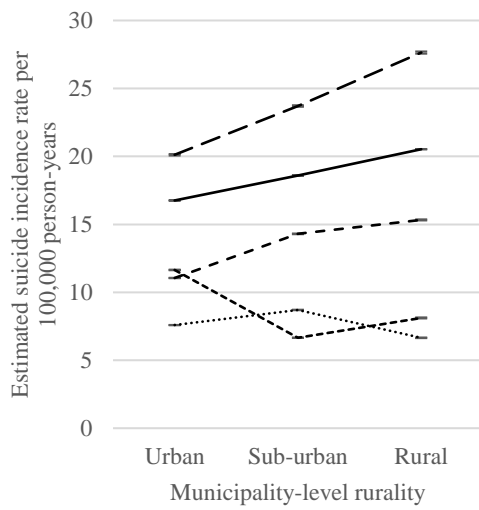
There was a cross-level interaction effects between country of birth and rurality among men, and the effects relied on the areal unit that used to evaluate rurality. The Pair Ratios for the estimated suicide rates in rural municipalities were 1.39 (95% CI: 1.38 to 1.40) among persons born in other European countries, 1.37 (95% CI: 1.36 to 1.39) among those born in other Nordic countries, and 1.23 (95% CI: 1.22 to 1.23) among the Swedish-born (Table 4 and Figure 2). The suicide risk among men born in Middle Eastern countries and the rest of the world was lower in rural municipalities than urban municipalities. At the neighborhood level, the excess risk in rural municipalities for men was observed in all categories of country of birth (Pair Ratios [95% CI] for those residing in rural neighborhoods: 1.24 [1.24 to 1.24] for Sweden, 1.12 [1.11 to 1.12] for other Nordic countries, 1.42 [1.41 to 1.43] for other European countries, 1.65 [1.61 to 1.69] for Middle Eastern countries, and 2.89 [2.85 to 2.92] for the rest of the world).

Table 4. Estimated Pair Ratio [95% Confidence Intervals] of suicide for residing in rural areas (vs. urban areas) by the areal unit that used to assess rurality by gender, Swedish registry-based cohort, 2011-2016.

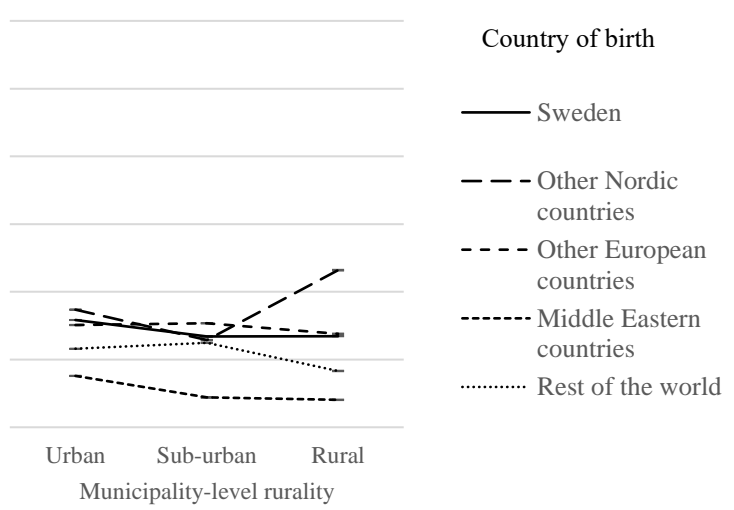
Country of birth	Areal unit for rurality definition			
	Municipality-level		Neighborhood-level	
Men				
Sweden	1.23	[1.22,1.23]	1.24	[1.24,1.24]
Other Nordic countries	1.37	[1.36,1.39]	1.12	[1.11,1.12]
Other European countries	1.39	[1.38,1.40]	1.42	[1.41,1.43]
Middle Eastern countries	0.70	[0.69,0.70]	1.65	[1.61,1.69]
Rest of the world	0.88	[0.87,0.88]	2.89	[2.85,2.92]
Women				
Sweden	0.85	[0.85,0.85]	0.82	[0.82,0.82]
Other Nordic countries	1.34	[1.33,1.34]	0.76	[0.76,0.76]
Other European countries	0.91	[0.91,0.92]	1.28	[1.27,1.29]
Middle Eastern countries	0.53	[0.53,0.54]	0.00	[0.00,0.00]
Rest of the world	0.72	[0.71,0.72]	0.59	[0.58,0.59]

a) Municipality-level rurality

Men

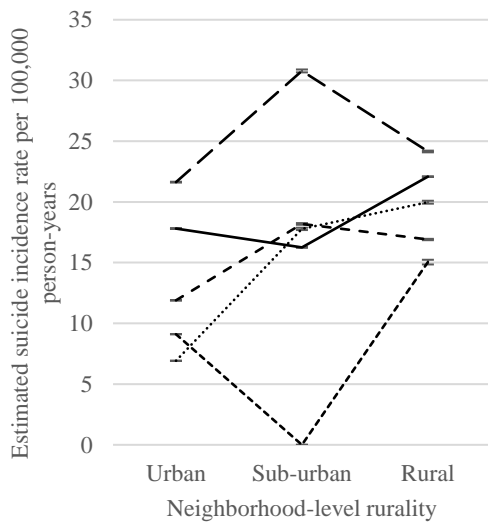


Women



b) Neighborhood-level rurality

Men



Women

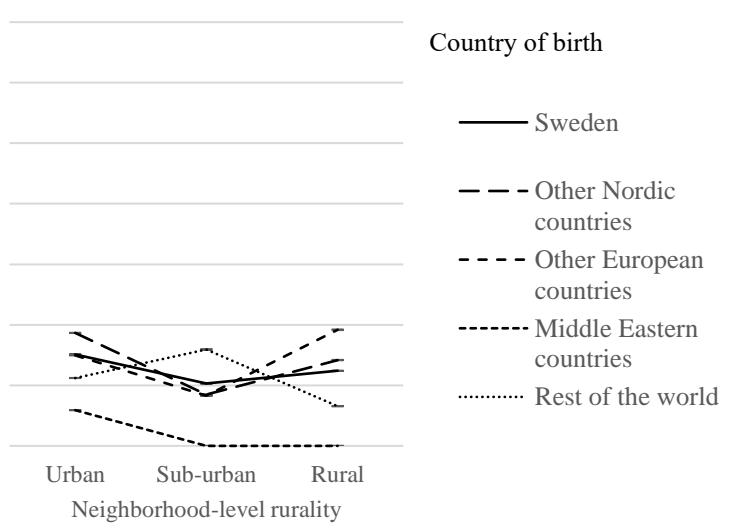


Figure 2. Estimated suicide incidence rates per 100,000 person-years with 95% confidence intervals by rurality, country of birth, and gender. The estimates were derived from three-level multilevel Poisson regression analyses adjusted for: a) age and neighborhood-level rurality; and b) age and municipality-level rurality.

The proportion of men with a low educational level and who had a partner was higher in rural municipalities/neighborhoods than urban municipalities/neighborhoods (Supplementary Tables 2 and 3). At the municipality-level, the percentage of unemployed was slightly higher in rural than in urban areas, while the opposite was true at the neighborhood level. Individual sociodemographic characteristics, including marital status, education, employment status, and disposable income quintile, explained 73.91% of the excess risk by municipality-level rurality among men, whereas it only slightly explained the excess IRRs due to neighborhood-level rurality (Table 2, Model 6).

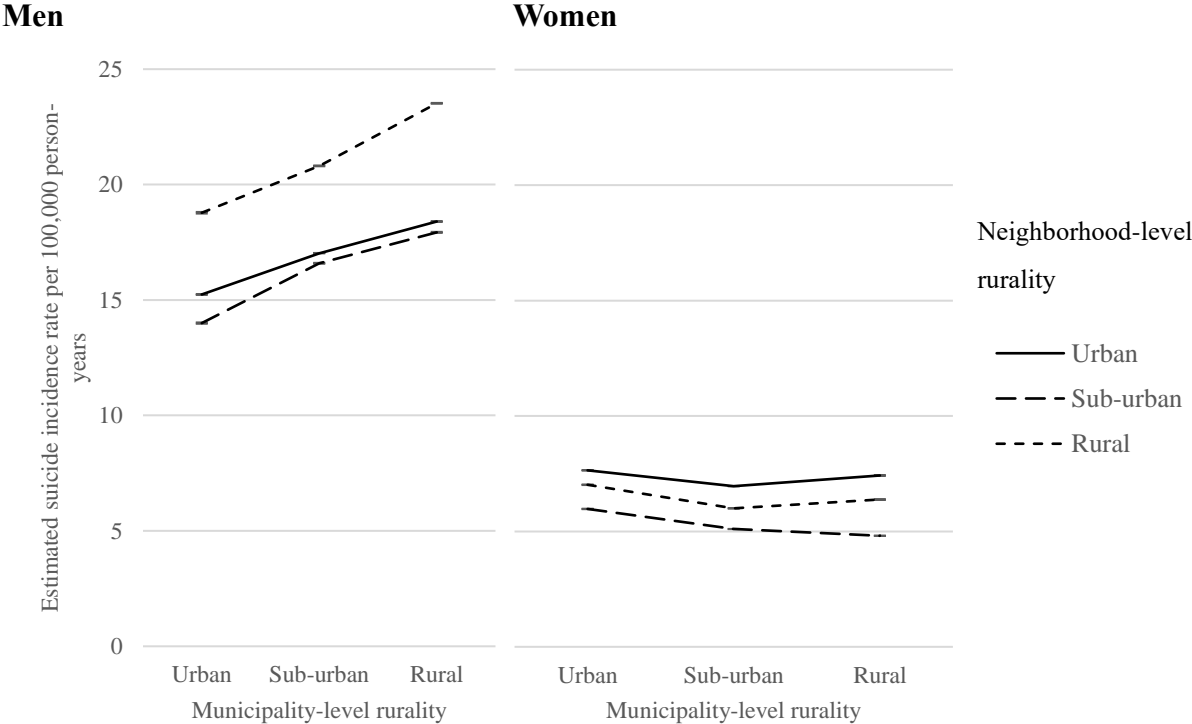


Figure 3. Estimated suicide incidence rates per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide. The estimates were derived from three-level multilevel Poisson regression analyses adjusted for age, country of birth, municipality-level rurality, and neighborhood-level rurality.

Among women, urban residents had a slightly higher suicide incidence than rural residents (IRR 0.97 for those residing in rural municipalities and IRR 0.84 for those residing in rural neighborhoods; Table 3). Analyses with cross-level interaction terms between country of birth and rurality showed that the excess risk of suicide among those residing in rural municipalities or rural neighborhoods, compared to urban municipalities or urban neighborhoods, was only observed in those born in other Nordic countries or in other European countries, respectively (Table 4 and Figure 2). Socio-demographic characteristics by rurality were quite similar to those of men (Supplementary Tables 2 and 4). After adjusting for individual socio-demographic characteristics, the IRR for those residing in rural municipalities decreased to 0.83, while the IRR for those residing in rural neighborhoods increased to 0.91 (Table 3, Model 6).

After cross-level interaction terms between municipality-level rurality and neighborhood-level rurality were added to Model 5, men residing in rural neighborhoods in rural municipalities had the highest suicide rate, whereas women residing in urban neighborhoods in urban municipalities had the highest rate (Figure 3). This suicide patterning according to rurality was quite similar for all age groups (Supplementary Figure 1).

Our sensitivity analyses showed that the results of the regression models using the alternative municipality-level rurality classified by Eurostat were mostly the same as those in our original models (Supplementary Tables 7 and 8, Figures 2 and 3). The multilevel survival models also produced almost identical results to those in our original Poisson models (Supplementary Tables 9 and 10, Figures 4 and 5).

2.4. Discussion

We found urban-rural inequalities in the incidence of suicide mortality among foreign-born and native Swedish adult men. Examining the effects of country of birth when evaluating rurality at the municipality level revealed that the excess suicide risk from residing in rural municipalities was higher among men born in other European or Nordic countries than among native Swedes. When evaluating rurality at the neighborhood level, the excess risk from residing in rural neighborhoods was higher among men born in the rest of the world, Middle Eastern countries, and other European countries than among native Swedes. While the IRRs of men born in Middle Eastern countries and the rest of the world were high if they resided in rural neighborhoods, this was not the case for rural municipalities. The excess risk of residing in rural municipalities among men was explained by their individual sociodemographic characteristics, whereas the excess risk of residing in rural neighborhoods was only slightly explained by this. On the other hand, women residing in urban areas generally had a higher suicide incidence than in rural areas, but we found no consistent patterning of the interaction with country of birth. To our knowledge, this is the first study to examine urban-rural inequality in suicide mortality using different units of aggregation while also accounting for differences by country of birth. Our finding of high suicide rates among foreign-born men living in rural areas is in line with the results of an Australian study from the 1990s [33], but the finding of high suicide rates among native Swedes in rural areas is not concordant with that study. Our novel findings suggest the existence of contextual factors affecting *all* men living in rural areas regardless of their country of birth.

We found a different interaction between country of birth and rurality by the level of aggregation among men. Individual sociodemographic characteristics explained more of the rurality-suicide association in municipalities. We speculate that this is because municipalities are politically independent while neighborhoods are not, and municipalities have an effect on

sociodemographic characteristics through the labor market and social benefits. Swedish municipalities have a relatively high degree of political autonomy. Rural municipalities have faced several problems related to economic and demographic decline, including lower tax revenues and the cutback of public services [124]. Residents may have difficulty accessing mental health services and higher education, obtaining stable employment, and so on. Thus, the lack of stable job opportunities and available resources in rural municipalities might constitute a potential explanation for the excess suicide risk among European-born and native men in these areas, since area-level socioeconomic disadvantage has been linked to both a high suicide rate and suicidal behavior [39,40]. Further, foreign-born people may be further disadvantaged in terms of occupation-education mismatch and in terms of their exposure to discrimination [125,126]. Immigrants from Finland have historically formed the largest group of Nordic migrants in Sweden. Finns generally have higher suicide rates than Swedes [25], and it is possible that this higher suicide risk persists when they have migrated to Sweden. Statistics also show that they are more likely to be single and unemployed, and to have a low education, compared to native Swedes [127]. These are well-known risk factors for suicide [52–54,102]. Among women, individual sociodemographic characteristics were also associated with suicide in rural municipalities, which is consistent with the mechanisms discussed.

On the other hand, in our analysis, men's excess suicide risk in rural neighborhoods was only slightly explained by individual sociodemographic characteristics. Thus, other factors are needed to explain this disparity. Compared to urban communities, rural communities generally have rich social ties and cohesive characteristics within the local community [128]. While numerous studies have reported that social relationships are positively associated with good mental and physical health [129], there is also some evidence that overly strong ties might also harm health due to an "exclusion of outsiders" and

“restrictions on individual freedom,” which Portes (1998) suggests constitute a dark side of cohesive communities [130]. Foreign-born men might suffer more than native Swedish men from these negative effects of cohesive rural communities. In addition, difficulty with acculturation and discrimination against ethnic minorities might exaggerate the suicide risk among foreign-born men. Wiking et al. (2004) reported that the self-rated health of immigrants from the Middle East in Sweden was poorer than that of native Swedes, which was largely explained by poor Swedish language proficiency and discrimination [131]. Although the suicide rate among individuals born in the Middle East has generally tended to be lower than that of native Swedes [86], the high IRR observed in rural neighborhoods among the Middle Eastern-born in this study might be due to disadvantages in social interactions in their local communities.

We found an excess suicide risk from residing in rural areas mostly only among men. The perspective of socially constructed masculinities in rural areas may be useful in explaining this [132]. Alston (2012) argued that the disadvantaged context in rural areas could be deeply associated with the construction of dominant masculine norms like stoicism – pushing on through hardship, illness, and despair [46]. Consequently, rural masculinities may restrict men in taking advantage of social support from friends and family, and may serve as a barrier to help-seeking behavior [133]. Although Sweden is known to be a highly gender-equal country, with a Gender Inequality Index ranked fourth in 2015 [134], and has seen nationwide political and structural action aimed at expanding women’s social roles, Backhans et al. have argued that this has done little to change the behavioral patterning of gendered norms [135]. Thus, it may be difficult for men in rural regions to access mental health services.

Although the excess risks for residing in rural areas were observed predominantly among men, it is important to emphasize that the gender difference in the association between

rurality and suicide risk is complicated and relates to the gender paradox in mental health. Men are overrepresented in terms of completed suicides, while the prevalence of mental health problems and suicide attempts is higher in women [136]. Future studies should examine the association between rurality and other indicators of mental health problems, such as psychiatric hospitalization, suicide attempts, or use of psychotropic medication.

The order of suicide rates among countries of birth was generally similar between urban and rural areas in Sweden: other Nordic countries, Sweden, other European countries, Middle Eastern countries or the rest of the world, in that order. In addition, the crude suicide incidence by country of birth obtained in this study tended to be similar to the suicide rates in each country, especially for those individuals from the middle East and other Nordic countries (Supplementary Figures 6 and 7). This is consistent with the finding from a previous review, which suggested that origin-specific contextual factors such as the culture of the birth country continue to exert an influence in the destination country [90]. By comparing urban and rural suicide rates in the same country of birth category, this study focuses on contextual factors in the destination country rather than those in the country of birth.

Although the lower suicide rate observed among people born in the Middle Eastern countries compared to those born in Sweden is consistent with previous studies [86], it should be noted that a lower risk for completed suicide in this group does not necessarily mean there is a lower risk of suicidal behavior. Specifically, although religious-related factors in the country of birth, such as taboos against suicide and healthy lifestyles, can be associated with a lower suicide risk [96,97], Awaad et al. (2021) recently reported that Muslims in the United States were two times more likely to have a history of suicide attempts compared to other religious groups in the country [137]. A study in Israel has also shown that self-reported suicide attempts were higher among Muslims than Jews, whereas suicide attempts diagnosed in a hospital and registered in the national database were lower [96], suggesting that social

pressure may influence the reporting of suicidal behaviors of this group in the official statistics.

In this study, we included people who were 20 years or older at baseline. Thus, the majority of the study population had entered the labor market or tertiary education in Sweden. This facilitates studying the contribution of sociodemographic factors in our models.

Our study has notable strengths. Although the concept of rurality has many geographical, political, and cultural dimensions, our rurality indicators were based on population density and distance from city areas, which have been reported to be sensitive to the relationship between rurality and suicide in a comparison of urbanicity indicators [13]. The similarity of the results using two different forms of municipality-level rurality strengthens the robustness of the findings. The use of total population data for Sweden is also a strength of our study. The mechanisms and processes linking rurality and suicide discussed in this paper might also be relevant in other countries, and should therefore be tested. Furthermore, our study can act to stimulate research on the rurality-suicide association in different migration groups in other countries, as there is currently little evidence within the field.

This study also has several limitations. First, misclassification can occur when the cause of death is registered as suicide; it may be classified as an injury-related death, traffic death, undetermined, and so on [138]. Further studies should take these diagnoses into consideration and confirm the robustness of the results. Second, we did not consider migration within Sweden during the observation period as we found that regression models assessing changes of address were too complex to calculate estimates. Evaluating the interaction effects of domestic and international migration should be another independent topic for future studies. However, in general, there are more immigrants moving to cities than to rural areas [139], and in our study we placed people in the rural resident category if they

resided in a rural area in 2011, regardless of the actual duration of their rural residence. This may have led to an underestimation of the excess suicide rates in rural areas. Third, as the number of suicides among people born in Middle Eastern countries was very small, the association between suicide and rurality among these people should be interpreted with caution. Further studies should examine long-term trends and confirm the robustness of the findings. Fourth, the countries of birth categories we used in this study might not fully capture the characteristics of different birth countries, and there may be some country of birth populations for which the mechanisms discussed are difficult to apply. Fifth, since information on occupations was not available, the industrial structure in urban and rural areas could not be examined in this study.

3. Study 2: Does increased migration affect the rural–urban divide in suicide?

3.1. Objectives

In Sweden, where immigration has been increasing, refugees/immigrants have increasingly settled in rural areas. Considering this increasing influx of immigrants into the rural population and changes in the rural environment, Study 2 examined whether trends in suicide mortality vary by country of birth and rurality, using Swedish national register data between 1991 and 2015 to perform a series of repeated cohort analyses with 5-year follow-ups. To explore how the mechanisms and processes linking rurality and suicide vary across time, we also examined whether area-level sociodemographic characteristics account for the association between rurality and suicide in each cohort.

3.2. Methods

3.2.1. Data

As in Study 1, we used multiple linked Swedish registry data that covered the total Swedish population. Using the 25 years of available registry data between 1991 and 2015 for all individuals who were aged 20 years old and above at baseline, we created population cohorts and followed up them. Specifically, to capture the dynamic changes in the population such as migration increases over time, five cohorts were created with five different analytic time periods. As our goal was to investigate trends in the suicide rate over time, we included as many cohorts as possible with the available data. We set 1991 as the baseline year for the first cohort, and reset baselines at five-year intervals based on the registered information as follows; 1996, 2001, 2006, and 2011. Individuals were followed up until whichever was earliest; suicide, censoring (deaths excluding suicide or emigration), or the end of follow-up

in 1995, 2000, 2005, 2010, and 2015, respectively.

3.2.2. Study population

As shown in Supplementary figure 8, we excluded the data of individuals (1) that were duplicated, (2) who were missing residential information, and (3) who were missing an individual ID number. To estimate area-level socioeconomic status, we also excluded (4) people who lived in very small neighborhoods (50 residents or fewer). In contrast to Study 1, we excluded data with only municipality-level residence information and missing neighborhood-level (DeSO) information, because the reason for the missing data was not clear and thus difficult to interpret. Data were missing for 1.01% of the study population in 1991 and 0.20% in 2011. In each cohort, a total of between 3.1 and 3.6 million men and 3.3 and 3.7 million women nested within about six thousand neighborhoods in 290 municipalities met our inclusion criteria (see Supplementary Figure 8 for details).

3.2.3. Measurements

3.2.3.1. Outcome and country of birth

The outcome is suicide, classified using ICD codes for intentional self-harm (ICD9: E950-E959; ICD10: X60-X84, Y870). Since the number of suicides was very small in some country of birth categories used in Study 1, we classified country of birth into the following three categories to observe stable trends: Sweden, European countries (Denmark, Finland, Norway, Austria, Bosnia–Herzegovina, Estonia, France, Greece, Italy, Yugoslavia, Croatia, the Netherlands, Poland, Romania, Russia, Spain, The United Kingdom of Great Britain and Northern Ireland, Czech Republic, Turkey, Germany, Hungary, and other European countries), and non-European countries (Iraq, Iran, Lebanon, Syria, and the rest of the world). According to the Swedish resident population trends by country of birth for 1991-2011 (Supplementary

Table 11), there was a sharp increase in the number of people born in Iraq and a decrease in the number of people born in Finland throughout the period for both men and women. In the 1990s, there was an increase in those born in Yugoslavia, Bosnia and Herzegovina, and an increase in the number of people born in Poland after 2001. The composition of the top 10 countries by country of birth remained largely unchanged, except for the inclusion of the male population from Somalia and the female population from Thailand in 2011.

3.2.3.2. Rurality

Since the mechanisms and processes linking rurality and suicide seem to differ by the unit of aggregation used to evaluate rurality as shown in Study 1, we used two different units of aggregation for studying the impact of rurality - municipalities and neighborhoods. To evaluate rurality at the municipality-level, we used the municipal population density tertile at the baseline year in each cohort (urban, sub-urban, rural). To evaluate rurality at the neighborhood-level, we used DeSO area-level measure at the baseline year in each cohort as in Study 1.

3.2.3.3. Area-level sociodemographic characteristics

We used the proportion of foreign-born people per the neighborhood population as a measure of social isolation, the proportion of unemployed and the proportion of people with the lowest income quintile per the neighborhood population as measures of socioeconomic status. These variables were calculated in aggregate by each neighborhood at baseline in each cohort; dividing the number of foreign-born individuals, the number of the unemployed, and the number of people in the lowest income quintile by the population, respectively.

3.2.4. Statistical analysis

We calculated IRRs from multi-level Poisson regression analyses with a three-level (individuals, neighborhoods, and municipalities) random intercept model, using the statistical package STATA/MP 15.1 (StataCorp, LLC, College Station, Texas, USA). We calculated person-years for each individual using the time from baseline to suicide or censoring, and used the logarithm of the person-years as an offset. As suicide has different incidence rates by gender and age, all the analyses were stratified by gender and adjusted for age (20-29, 30-39, 40-49, 50-59, 60-69, and over 70).

We firstly calculated suicide incidence rates per 100,000 person-years, stratified by gender, age, country of birth, and rurality for each cohort. To evaluate the cross-level interaction for suicide between rurality and country of birth, we included the following variables: municipality-level rurality, neighborhood-level rurality, country of birth, and an interaction term between rurality and country of birth. Second, from the estimates obtained from the model for those who reside in urban and rural areas according to year, we calculated Pair difference and Pair ratios for rural areas (reference: urban areas) by country of birth, using the Health Disparity Calculator version 2.0.0 [120], to evaluate the magnitude of the urban-rural suicide gap. The Pair Differences in the suicide rate between urban and rural areas refer to the simple arithmetic difference between the two groups. Also, the Pair Ratios in the rate are calculated by dividing a group by a reference group. Details of these measures and how to calculate them are available elsewhere [121]. To assess how the effect of neighborhood-level rurality differs according to municipality-level rurality, we also conducted interaction analyses with the following variables: municipality-level rurality, neighborhood-level rurality, and country of birth, and an interaction term between municipality-level and neighborhood-level rurality. Then we plotted the estimated suicide incidence rates from the models, and visually evaluated the secular trends in suicide rates by

country of birth, rurality, and gender.

In addition, we explored whether area-level sociodemographic characteristics explain the differential suicide rate across rural areas. To do this, we conducted three-level Poisson regression analyses. Model 1 included the following variables: municipality-level rurality, neighborhood-level rurality, and country of birth. Models 2-4 included the variables in Model 1 and area-level sociodemographic factors; the proportion of foreign-born people per the neighborhood population in Model 2, the proportion of unemployed per the neighborhood population in Model 3 and the proportion of people with the lowest income quintile per the neighborhood population in Model 4. We calculated the percentage change in the excess suicide rate between Model 1 and Models 2-4 among those residing in rural areas compared to those in urban areas. To evaluate the magnitude of the effects of areal-level sociodemographic characteristics, we calculated MRR from the estimated variance in the random parameters of the multilevel models.

3.3. Results

Descriptive data for each year showed that, in general, suicide rates per 100,000 person-years for both genders were higher among those born in European countries, followed by those born in Sweden and non-European countries (Table 5, Supplementary Table 12 and 13). Cross-level interaction analyses showed that these associations were similarly observed for most of the cohorts, with higher suicide rates among men residing in rural areas than in urban areas (Figure 4 and Figure 5, and Supplementary Table 14 and 15). Pair difference and Pair ratios showed that the urban-rural gap in suicide mortality was generally higher among foreign-born than Swedish-born men (Supplementary Figure 9 and 10). The estimated suicide rate for men appeared to decrease, gradually, over the observation period among all birth

country groups. However, around 2001, the suicide rates of foreign-born men residing in rural neighborhoods clearly fluctuated, with a seeming increase in their suicide rates, especially in the non-European countries group (Figure 5 and Supplementary Table 15). Indeed, among men from non-European countries health inequality measures of suicide appear to have increased between urban and rural neighborhoods since the early 2000s (Supplementary Figure 10). Among women, we observed a decrease in the suicide rate in urban areas irrespective of country of birth while no such trend was found in rural areas except among women from non-European countries in rural neighborhoods (Figure 4 and Figure 5, and Supplementary Table 16 and 17). The difference and ratio of rural suicide rates to urban suicide rates tended to increase slightly over the years (Supplementary Figure 9 and 10).

Table 5. Suicide rates by country of birth and rurality among Swedish residents in selected cohorts (full data are available in the supplemental material).

	1991 cohort			2001 cohort			2011 cohort		
	Person-years	No. of suicides	Suicide rate ^a	Person-years	No. of suicides	Suicide rate ^a	Person-years	No. of suicides	Suicide rate ^a
Men									
Country of birth									
Sweden	13,596,611	3,193	23.5	13,931,785	2,702	19.4	14,511,267	2,654	18.3
European countries	1,151,504	292	25.4	1,297,959	279	21.5	1,572,962	245	15.6
Non-European countries	428,927	62	14.5	710,235	80	11.3	1,301,420	107	8.2
Municipality-level rurality^b									
Urban	9,060,608	2,025	22.3	10,180,748	1,826	17.9	11,468,675	1,862	16.2
Sub-urban	3,835,886	889	23.2	3,584,724	750	20.9	3,738,519	682	18.2
Rural	2,280,548	633	27.8	2,174,507	485	22.3	2,178,455	462	21.2
Neighborhood-level rurality^c									
Urban	10,801,717	2,443	22.6	11,561,147	2,097	18.1	12,825,500	2,084	16.2
Sub-urban	1,409,033	325	23.1	1,409,497	278	19.7	1,506,110	254	16.9
Rural	2,966,292	779	26.3	2,969,335	686	23.1	3,054,039	668	21.9
Women									
Country of birth									
Sweden	14,271,104	1,355	9.5	14,436,917	1,043	7.2	15,404,059	1,096	7.1
European countries	1,367,087	172	12.6	1,555,733	157	10.1	1,788,760	149	8.3
Non-European countries	356,038	22	6.2	702,829	47	6.7	1,336,754	66	4.9

Municipality-level rurality^b							17,865,650		
Urban	9,790,458	1,045	10.7	10,844,619	877	8.1	11,934,359	898	7.5
Sub-urban	3,922,492	315	8.0	3,667,541	249	6.8	3,781,003	257	6.8
Rural	2,281,279	189	8.3	2,183,319	121	5.5	2,150,288	156	7.3
Neighborhood-level rurality^c									
Urban	11,826,243	1,247	10.5	12,497,396	1,014	8.1	13,534,632	1,036	7.7
Sub-urban	1,433,760	112	7.8	1,451,391	80	5.5	1,526,990	83	5.4
Rural	2,734,226	190	6.9	2,746,692	153	5.6	2,804,028	192	6.8

^a Suicide incidence per 100,000 person-years

^b We used population density as a marker of municipality-level rurality.

^c For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

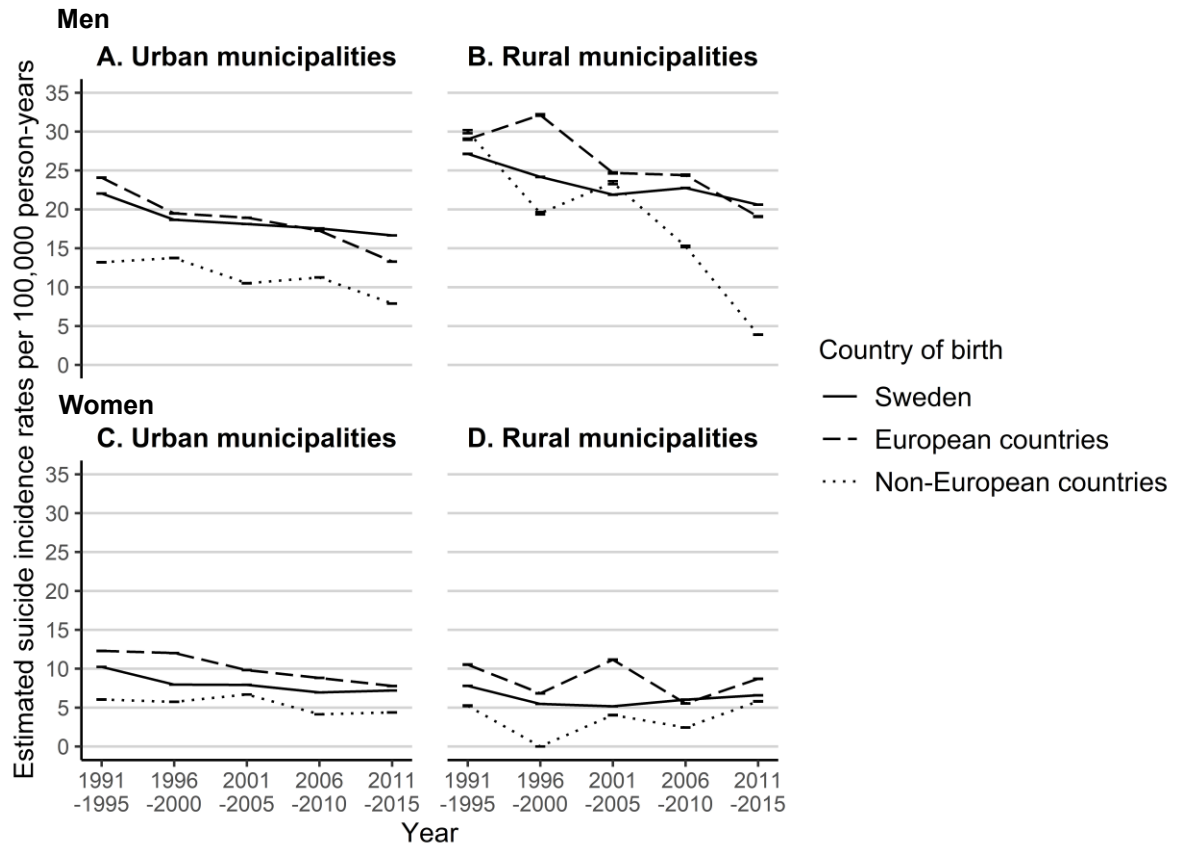


Figure 4. Estimated suicide incidence rates per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between country of birth and municipality-level rurality on suicide. A/C shows the estimates among men/women residing in urban municipalities, and B/D shows the estimates among men/women residing in rural municipalities. The estimates were derived from three-level multilevel Poisson regression analyses adjusted for age and neighborhood-level rurality. The model estimates are available in the supplemental material.

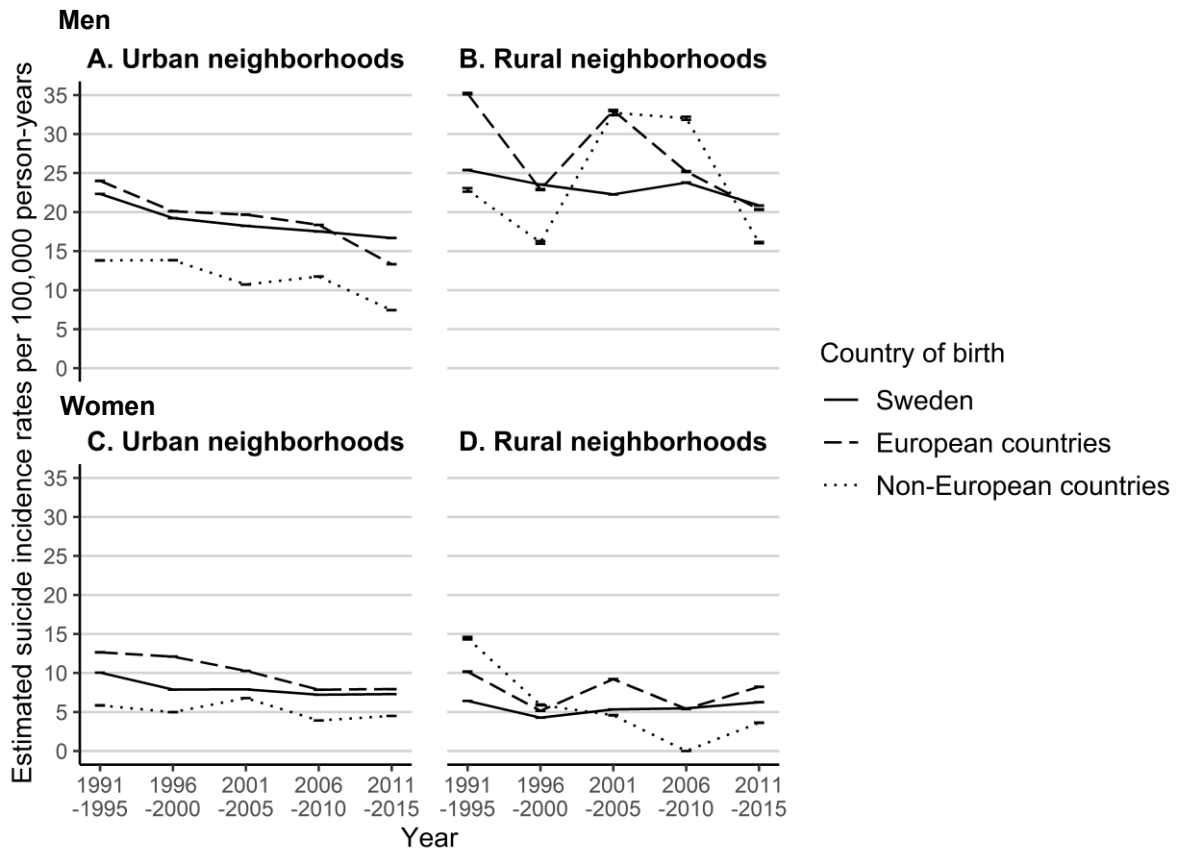


Figure 5. Estimated suicide incidence rates per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between country of birth and neighborhood-level rurality on suicide. A/C shows the estimates among men/women residing in urban neighborhoods, and B/D shows the estimates among men/women residing in rural neighborhoods. The estimates were derived from three-level multilevel Poisson regression analyses adjusted for age and municipality-level rurality. The model estimates are available in the supplemental material.

Male suicide rates were consistently higher among those residing in rural areas compared to urban areas, whereas female suicide rates were the opposite (Table 5, Supplementary Table 12 and 13). These associations were similarly observed in regression analyses adjusted for age and country of birth, with the IRR for residing in rural municipalities (ref: urban municipalities) ranging between 1.16 (95% CI 1.03 to 1.31) and 1.26 (1.12 to 1.41) in men and 0.76 (0.62 to 0.94) and 1.01 (0.83 to 1.22) in women, while the IRR for residing in rural neighborhoods (ref: urban neighborhoods) ranged between 1.07 (0.98 to 1.17) and 1.26 (1.14 to 1.38) in men and 0.59 (0.49 to 0.72) and 0.88 (0.74 to 1.04) in women (Supplementary Table 18). Interaction analyses showed that men residing in rural neighborhoods in rural municipalities had the highest suicide rate, with suicide rates in both rural and urban groups declining over time (Supplementary Figure 11). However, for women, suicide rates among those who resided in urban neighborhoods in urban municipalities were highest among the categories, while urban-rural differences in rates were less clear in the later period.

After including area-level variables in the regression model using the male cohorts as shown in Table 6 and Supplementary Tables 19-22, the proportion of unemployed was linked to 36.8%, 50.0%, 93.8%, 77.8%, and 82.4% of the excess suicide rate associated with residing in rural municipalities in the 1991, 1996, 2001, 2006, and 2011 cohorts, respectively. On the other hand, the neighborhood-level rurality coefficient increased. MRRs decreased by 0.01-0.05 between municipalities and by 0.02-0.10 between neighborhoods, indicating that the proportion of unemployed residents was linked to 1-5% of the variance in suicide between municipalities and 2-10% of the variance between neighborhoods. The proportion of people with the lowest income quintile per the neighborhood population also underpinned 85.7%, 127.3%, 68.8%, 26.9%, and 20.0% of the excess risk for suicide associated with residing in

rural neighborhoods in the 1991, 1996, 2001, 2006, and 2011 cohorts, respectively. Note that the IRR of residing in rural neighborhoods was relatively smaller in the 1991 and 1996 cohorts than in the other cohorts. The proportion of people with the lowest income quintile also accounted for 5.3%, 3.8%, 31.2%, 11.1%, 5.9% of the excess risk for suicide associated with residing in rural municipalities in the 1991, 1996, 2001, 2006, and 2011 cohorts, respectively. MRRs changed little either between municipalities or neighborhoods, indicating that the proportion of people with the lowest income quintile did little to account for the variance in suicide between areas. When we added the proportion of foreign-born people, the municipality-level and neighborhood-level rurality coefficients increased. Since excess suicide mortality associated with residing in rural areas was observed only among men, these analyses were not conducted among women.

Table 6. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 2011 -2015 Swedish registry-based cohort data (results of other cohorts are available in the supplemental material).

	Model 1		Model 2		Model 3		Model 4	
Municipality-level rurality^a								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	1.04	[0.93,1.16]	1.09	[0.98,1.22]	0.96	[0.86,1.07]	1.04	[0.93,1.16]
Rural	1.17	[1.03,1.33]	1.24	[1.09,1.40]	1.03	[0.91,1.17]	1.16	[1.02,1.32]
<i>% change from Model 1 in excess rate from urban</i>			41.2%		-82.4%		-5.9%	
Neighborhood-level rurality^b								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.97	[0.84,1.11]	1.04	[0.91,1.20]	1.02	[0.89,1.17]	0.98	[0.85,1.13]
Rural	1.20	[1.09,1.33]	1.32	[1.19,1.46]	1.32	[1.19,1.46]	1.16	[1.05,1.29]
<i>% change from Model 1 in excess rate from urban</i>			60.0%		60.0%		-20.0%	
Proportion of foreign-born people per neighborhood population (/person)			3.95 [2.76,5.65]		7.83 [4.96,12.35]			
Proportion of unemployed per neighborhood population (/person)							7.91 [3.60,17.39]	
Proportion of people with the lowest income quintile per neighborhood population (/person)								
<i>Random-effect part of the Model</i>								
Median rate ratios between municipalities								
Null=1.23	1.17		1.17		1.16		1.18	
Median rate ratios between neighborhoods								
Null=1.35	1.35		1.32		1.31		1.34	

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Model 1: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 2: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of foreign-born people per neighborhood population

Model 3: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of unemployed per neighborhood population

Model 4: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of people with the lowest income quintile per neighborhood population

3.4. Discussion

In line with Study 1, we found a continuously high suicide rate among men who reside in rural areas in Sweden, with a stronger impact of the rural context seen in foreign-born men. Although in general, the suicide rate for men decreased over time in both urban and rural areas in Sweden, we observed fluctuations among foreign-born men residing in rural neighborhoods, with high suicide rates in the 2000s. When we evaluated rurality at the municipality-level, the proportion unemployed was associated with the excess suicide rate. On the other hand, when we evaluated rurality at the neighborhood-level, the proportion of people with the lowest income quintile per the neighborhood population was partly associated with the excess suicide rate. Among women, suicide rates for all country of birth groups tended to decline only in urban areas between 1991 and 2015, whereas no such trend was observed in rural areas.

A seemingly increasing trend in suicide mortality was seen among foreign-born men residing in rural neighborhoods around the 2000s, whereas no such trend was observed when evaluating the effects of rurality at the municipality level. These differing trends by the areal unit of aggregation may be key for understanding the association between rurality and suicide. As we discussed in Study 1, as the municipality is the smallest politically independent unit in Sweden, municipality-level rurality might better reflect socioeconomic factors such as local labor market characteristics. Residents in rural municipalities may be exposed to a higher risk of unemployment or precarious working conditions which are well-known risk factors for mental health problems and suicide [54,124]. Accordingly, we found that unemployment played a role in the excess suicide rate in rural municipalities although it did not affect the association in rural neighborhoods. Indeed, it is noteworthy that unemployment only accounted for a small percentage of the regional variation in suicides, and there may be other factors that better explain the regional differences in suicides. In addition, Dunlavy et al. have

suggested that the magnitude of the effect of unemployment on suicide varies with migration background characteristics, and is smaller for non-European immigrants and those with shorter periods of Swedish residency [140]. If this is correct, it is possible that the increasing growth of refugees in rural municipalities, i.e., more migrants with shorter periods of residence, may help explain the observed decrease in suicide rates among non-European immigrants in rural municipalities.

As a possible explanation for the excess suicide rate among men residing in rural neighborhoods, area-level socioeconomic disadvantage, a well-known risk factor for suicide, may be relevant here [39,40]. An economic recession hit Sweden between 1990 and 1994, followed by an increase in income-based inequality in suicide mortality, especially after the late-1990s [38]. In the 1990s, the proportion of low-income people was more strongly associated with male suicide in rural areas than in more recent years. Given that this period coincided with a reported increase in individual-level income-based inequality in suicide mortality, to better understand more recent suicide trends it might be beneficial to focus on various area effects that link place to health such as the negative aspects of the community context influenced by the economic recession in the earlier period. We speculate that this might help explain the high suicide rate among foreign-born men residing in rural neighborhoods from around the year 2000. Using a case study of a small rural Swedish town at the time of the economic crisis, Wigerfelt and Wigerfelt described everyday racial violations towards refugees/immigrants, which included blaming them for consuming scarce resources in their local community [101]. Economic crises have been associated with an increase in discrimination and harassment by some vulnerable groups toward other vulnerable groups [141]. In rural settings, representations of outsiders may be amplified to a greater extent than in urban areas, and people with foreign backgrounds may suffer racist discrimination to a much greater extent than in urban settings [99,100]. This may have been

important as previous research has linked discrimination and other forms of harassment to suicide [103].

Also of note is the impact of the high suicide rate in rural areas. For example, we can readily calculate the number of adjusted suicides by multiplying the suicide rate estimated from the model and study population number shown in Supplementary Table 23. The estimated number of suicides in rural neighborhoods from the 2001 cohort, which showed a marked fluctuation in the rate among foreign-born men residing in rural neighborhoods, is around 10 per year among the foreign-born population and about 128 per year among the native population. Note that the total number of suicides observed in the 2001 cohort, which lasted for five years, was 3,061 (specifically 686 in rural neighborhoods). Given that suicide is generally a rare outcome, we should be cautious in assessing changes in suicide rates stratified by country of birth. However, for each adult who dies of suicide it has been estimated that there may be as many as 20 attempted suicides [87], and suicide bereavement can negatively affect the mental health of families, friends, and communities [142–144]. Furthermore, Hjern and Allebeck (2002) reported that the suicide rate among the youth population of second-generation immigrants whose parents were both born abroad was higher than that of their parents' generation [145]. Our findings highlight the need for long-term equitable measures that cover more vulnerable people who lack resources. Since the proportion of foreign-born people at the neighborhood level was associated with increasing differences in urban-rural suicide rates, it may be an important factor in the excess suicide mortality in urban communities with large immigrant populations. In light of the fact that many migrants move from rural areas to urban areas, suicide prevention in rural areas may also be positioned as an upstream factor in many problems that occur in urban areas.

The association between rurality and suicide was different depending on the specific gender. In various countries, since the 1960s, the suicide rates of women in rural areas have

increased or stayed the same, even if the rates in urban areas decrease [9,11,22,29]. Although the timing and speed of rising female suicide rates in rural areas seems to vary among countries, this common tendency has been observed. A recent report from the United States pointed out that female suicide rates in rural areas have overtaken those in urban areas [10]. Therefore, there is a possibility that in Sweden, the suicide rates of women in rural areas will be higher than those in urban areas in the future. Considering that the female suicide rate in Sweden was the seventh highest among Organization for Economic Co-operation and Development (OECD) countries in 2017 [146], continual evaluation of the variation in suicide rates by rurality may be important going forward.

The potential role of Swedish health equity policies and suicide prevention programs should also be noted with regard to the general decrease in suicide rates among men during the observation period (Supplementary Table 24). In Swedish public health policy, health inequality issues have been part of the political agenda since the 1980s [147]. Following the recommendations of the World Health Organization's Commission on Social Determinants of Health (SDH) in 2008 [148], efforts to reduce health inequity began at the local level from 2010 onwards, and in 2014 the Swedish Prime Minister declared that the goal was to reduce avoidable health inequalities within a generation, resulting in the establishment of a national Commission for Equity in Health in 2015 [147]. Regarding suicide prevention measures, after the first national suicide prevention program was established in 1995, a second comprehensive program was created in 2008 [149]. It included a variety of measures such as reducing access to the means of suicide and improving health care services, while also emphasizing the importance of social insurance and labor market policies for socially vulnerable groups, and reducing alcohol consumption in the general population, which is in line with the SDH approach [150]. Its attempt to reduce prejudice against suicide by framing it as a psychological mistake may also be important in light of the increasing migration in

Sweden [150]. Despite the global economic crisis in 2008, the country's overall suicide rate declined three and six years after the program was implemented, especially among older men [151]. Suicide prevention measures that further incorporate social determinants of health at various levels may be beneficial in the future.

Limitations of this study include the possibility that the association between rurality and suicide may not have been due to the contextual effects in rural areas, but rather, to the concentration of socially vulnerable residents in rural areas. Although areal assignment for refugees through dispersion policies could be considered as exogenous, they were able to freely change their residential address after the assignment, but our models did not incorporate internal migration. In addition, the analytical method we have used to explore the mechanisms that link rurality to suicide is a crude approach. The observed reduction in the effects when adding neighborhood-level sociodemographic factors reflects both mediation and confounding/selection. Studies of the rurality-suicide association in different migratory groups should be examined further, with a more comprehensive analytic design such as a natural experiment to test causal associations. Moreover, suicide deaths can be misclassified as injury-related deaths, traffic deaths, undetermined, and so on [138]. Evidence on the regional variation of the likelihood of this misclassification may help to clarify whether the results of this study were overestimated or underestimated.

4. Conclusions

4.1. Summary of the two studies

This dissertation aimed to elucidate urban-rural differences in suicide mortality in Sweden from three perspectives: the country of birth of the residents, the areal unit used to evaluate rurality, and the link to sociodemographic factors. We conducted two types of registry-based cohort study covering the total Swedish adult population. Study 1 aimed to examine the impact of rural living on suicide mortality by country of birth and whether individual characteristics explained urban-rural differences in suicide rates. In Study 2, focusing on the changes in rural areas in recent decades, specifically the increase in the refugee/immigrant population, we aimed to elucidate the 25-year trend in urban-rural differences in suicide mortality and determine area-level factors that could explain the differences.

We found that men in rural municipalities/neighborhoods had a higher suicide risk than those in urban areas regardless of country of birth, with a potentially stronger impact of residing in rural municipalities/neighborhoods among foreign-born men. This tendency was observed consistently throughout the period between 1991 and 2016. In general, male suicide rates in both urban and rural municipalities/neighborhoods continuously decreased across the study period, except for those of foreign-born men in small rural communities. The excess risk of suicide among men residing in rural municipalities/neighborhoods implies that the community context may have a negative effect on male rural residents.

The cross-level interaction between rurality and country of birth on male suicide and the association between individual-level/area-level sociodemographic characteristics and urban-rural inequalities in male suicide depended on the geographic unit used to assess rurality. When evaluating rurality at the municipality level, we observed an increased suicide risk from living in rural areas among men born in European countries, including native Swedes. The excess suicide risk among men residing in rural municipalities was explained by

individual sociodemographic characteristics, including income, education, unemployment, and marital status. Regarding area-level factors, the proportion of unemployed persons was continuously linked to the excess suicide in rural municipalities across the 25 year period. These results at the municipal level suggest that individuals residing in rural municipalities may have less access to economic resources and employment opportunities.

When evaluating rurality at the neighborhood level, rurality was associated with an increased suicide risk in men for all country of birth groups, especially for those born in non-European countries. The excess risk in rural neighborhoods was not explained by individual-level sociodemographic factors and the proportion of the unemployed, but only partly by the proportion of low-income people. We speculate that income distribution and some psychosocial characteristics (e.g., ethnic discrimination) of smaller communities within municipalities might explain these findings.

In contrast to men, among women, urban residents generally had a higher suicide incidence than rural residents, regardless of country of birth or the areal unit used to assess rurality. Although many of the mechanisms discussed for men may be theoretically applicable to women, we were unable to discuss them in depth because we found few differences in the results across countries of birth or areal units to evaluate the potential effects of rurality among women. We discussed the possible role of restrictive gender norms (e.g., masculine norms like stoicism among rural men) in these gender differences in the relationship between rurality and suicide.

4.2. Further discussion of the study findings based on place effects perspectives

In this section, I will discuss the association between rurality and suicide revealed in this dissertation, in relation to the place effects perspectives by Macintyre et al. [41] that were

introduced earlier, that is, compositional and contextual explanations.

This study found that individual sociodemographic characteristics explained much of the excess suicide mortality in rural municipalities among men. There are two possible scenarios: (1) those who moved to rural municipalities became socially disadvantaged and experienced an increased suicide risk (i.e., individuals become socially disadvantaged because of the contextual features of the residential municipalities), or (2) socially disadvantaged people, who already had a higher suicide risk were more likely to move to rural municipalities before the observation started (i.e., selection). We were not able to distinguish between these two potential explanations in this study. Thus, it remains possible that the urban-rural difference in suicide at the municipal level was due to selection rather than due to the contextual features of municipalities.

On the other hand, when we focus on urban-rural differences in suicide mortality at the neighborhood level, contextual explanations may be appropriate because individual sociodemographic status explained little of the urban-rural difference in suicide mortality. The proportion of low-income people was associated with male suicide in rural neighborhoods in the 1990s, whereas it was less relevant from the late 2000s. We speculated that it might be due to negative aspects of the community context, such as ethnic discrimination, stigma, and exclusion from social networks and the community.

Based on the above discussion, I conclude that this study's findings at the municipality level may be partly due to sample selection, while the results at the neighborhood level reflect the contextual features of rural areas.

Our analysis showed that in the 2011 cohort, suicide rates among men from non-European countries were higher in urban areas than in rural areas, but selection bias may underlie this result. The country of birth category included many refugees. Regarding the acceptance of refugees, the Swedish government has had dispersion policies that directed

refugees to settle in rural areas to avoid population concentration in metropolitan areas [75,77]. Vogiazides and Mondani (2020) have analyzed refugee relocation trajectories in Sweden and reported that unemployed individuals tend to move more from rural to urban areas than employed persons [77]. Consequently, socially disadvantaged individuals may have clustered in urban areas (selection).

4.3. Implications for public health policies in Sweden

This study suggests that men born in European countries and Sweden residing in rural municipalities are at high risk for suicide, and individual sociodemographic status is associated with their excess suicide in rural municipalities. The health equality policies of the Swedish government focus on providing resources equitably that are important to health, such as opportunities for education, a living and working environment, income, and social participation [147]. It may be important to consider differences in characteristics between municipalities by rurality when it comes to providing public support, especially in relation to employment-related policies. Cross-sectoral collaboration within the local government, such as coordination of job seekers support, immigrant support, and mental health support, may be beneficial.

We found that there was a high suicide rate in small rural communities within municipalities. Further research is needed to understand the pathways linking the community context to suicide risk, with a special focus on low-income neighborhoods and the potential risk for social exclusion and discrimination of specific ethnic groups. Collecting information on contextual factors including political and normative features that exclude specific ethnic groups would be helpful. Considering the growing number of non-European migrants, refugees, and their second-generation offspring, monitoring the social environment

surrounding ethnic minorities is essential.

The health impact of the dispersion policies that directed refugees to settle in rural areas should be studied further. To the extent they were examined in this study, male suicide rates generally declined in all countries of birth between 1991 and 2015, indicating that it is unlikely that these policies have had a negative impact on suicide. However, it is still essential to pay particular attention to how the context of small areas within a municipality can affect refugees, immigrants, and native Swedes. To host the refugees, a collaborative form of governance has been developing between civil society and the public authorities, especially in rural areas [152]. Further investigation of the situation that refugees face, with attention to the differences between neighborhoods within municipalities may provide useful information.

4.4. Implications for future studies on urban-rural inequalities in suicide

Our finding of a differential suicide risk and the potential effects of residing in rural municipalities and rural neighborhoods warrants further study. Particularly, identifying relevant community characteristics, including local policies and cultural norms/behaviors, may contribute to public health interventions to prevent suicide and its inequalities by rurality, migration status, and gender. Using data on older people in Japan, my colleagues and I have reported that the association between rurality and depressive symptoms varies by the areal unit used to assess rurality [153]. In addition, how community social capital explained the link between rurality and depression varied by the areal unit. Community civic participation, the degree to which residents participate in community groups (i.e., volunteer groups, sports groups, and hobbies) or activities, was linked to municipality-level urban-rural differences in depression. On the other hand, community social cohesion, such as a sense of mutual trust, and reciprocity was associated with differences in depression between smaller units rather

than in municipalities. These findings suggest that the association between rurality and mental health, and the mechanisms linking them, may vary by the areal unit used to evaluate rurality. Thus, further attention on collective psychosocial factors may enhance understanding of the regional distribution of suicide.

Gender norms and health is an area that will need to be explored more. Although suicide is a health outcome that varies greatly between men and women worldwide, with higher rates of suicide mortality in men and more suicide attempts among women [136], gender differences in suicide may be pronounced in relation to rurality. As discussed in Study 1, the high suicide rate among rural men may be partly due to masculinity norms constructed in rural societies [46]. Gender relations can be relevant to health at various levels of society, and the social structure of gender relations has changed over time [154]. Gender norms and gender construction in a society/community possibly relate to whether people can escape from problems when suffering. Greater investigation of gender norms as social determinants of health may help develop effective public health interventions to tackle regional inequalities in suicide.

Outcome-wide studies that simultaneously compare multiple outcomes when examining the association between rurality and mental health are also important [155]. Differences in the prevalence of suicide attempts between urban and rural areas have varied markedly in the direction of the association across studies [2]. Admission to hospital for treatment of psychosis or depression was reported to be more common in urban areas than rural areas of Sweden in the late-1990s for both men and women [156]. When hospital-reported illnesses are used as the outcome, the association with rurality needs to be interpreted in light of regional differences in access to health care since only those diagnosed can be counted. Comparing regional differences in suicide deaths and other mental health outcomes may shed light on the impact of improved access to health and welfare services in

suicide prevention. It may also provide helpful insights into understanding gender differences in rurality and suicide.

The focus on the country of birth in this dissertation should be further deepened through comparative research with other countries. The findings of this study imply that some phenomena that can be framed as "immigrant's issues" may partly derive from how the social structure relates to urban-rural health inequalities that also exist among the native population. The presence of vulnerable immigrants may help to highlight this issue. This situation could be common across countries. For example, in Japan, against the backdrop of a labor shortage due to population aging and reduction in rural areas, several policies have been implemented to recruit foreign workers. However, the working environment of foreign workers who migrated to Japan as a result of these policies has been criticized by the United Nations Committee on the Elimination of Racial Discrimination [157]. In this context it is possible that disadvantages in socio-economic conditions, social relationships, and the living environment that are often observed more generally in rural areas might also underlie the issues that have been brought to attention by increased international migration [158].

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Supplemental materials for Study 1

Supplementary Table 1. Number of men and women by municipality-level rurality and neighborhood-level rurality.

Supplementary Table 2. Number of men and women by age, country of birth, sociodemographic characteristics, and municipality-level rurality.

Supplementary Table 3. Number of men by age, country of birth, sociodemographic characteristics, and neighborhood-level rurality.

Supplementary Table 4. Number of women by age, country of birth, sociodemographic characteristics, and neighborhood-level rurality.

Supplementary Table 5. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] for men: the full results of multilevel Poisson regression analysis.

Supplementary Table 6. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] for women: the full results of multilevel Poisson regression analysis.

Supplementary Table 7. Descriptive statistics of variables of the municipality-level rurality by Eurostat.

Supplementary Table 8. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] by gender: the results of multilevel Poisson regression analysis.

Supplementary Table 9. Suicide Hazard Ratios (HR) [95% Confidence Intervals] for men: the results of parametric multilevel survival analyses.

Supplementary Table 10. Suicide Hazard Ratios (HR) [95% Confidence Intervals] for women: the results of parametric multilevel survival analyses.

Supplementary Figure 1. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by rurality, age, and gender.

Supplementary Figure 2. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide.

Supplementary Figure 3. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by rurality, country of birth, and gender.

Supplementary Figure 4. Estimated survival probability with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide.

Supplementary Figure 5. Estimated survival probability with 95% confidence intervals by rurality, country of birth, and gender.

Supplementary Figure 6. Male suicide incidence rates by country of birth in Sweden and the male suicide rate in each country.

Supplementary Figure 7. Female suicide incidence rates by country of birth in Sweden and the female suicide rate in each country.

Supplementary Table 1. Number of men and women by municipality-level rurality and neighborhood-level rurality.

Municipality-level rurality	Neighborhood-level rurality			
	Urban	Sub-urban	Rural	Unknown
Men				
Urban	1,159,116	49,425	51,512	4,990
Sub-urban	973,576	139,756	265,335	3,323
Rural	523,468	122,031	312,318	1,637
Women				
Urban	1,217,818	50,630	47,293	1,811
Sub-urban	1,026,449	141,249	243,113	1,194
Rural	556,725	124,038	285,068	707

Supplementary Table 2. Number of men and women by age, country of birth, sociodemographic characteristics, and municipality-level rurality.

	Men						Women					
	Urban		Municipality-level rurality		Rural		Urban		Municipality-level rurality		Rural	
		(%)		(%)		(%)		(%)		(%)		(%)
Age												
20-29	236,807	(18.7)	255,944	(18.5)	146,053	(15.2)	238,746	(18.1)	239,708	(17.0)	128,649	(13.3)
30-39	261,569	(20.7)	223,876	(16.2)	131,589	(13.7)	253,657	(19.3)	214,567	(15.2)	125,491	(13.0)
40-49	248,077	(19.6)	249,948	(18.1)	166,286	(17.3)	242,096	(18.4)	240,822	(17.1)	159,758	(16.5)
50-59	196,574	(15.5)	222,000	(16.1)	164,644	(17.2)	193,715	(14.7)	219,576	(15.6)	160,835	(16.6)
60-69	176,839	(14.0)	227,619	(16.5)	180,379	(18.8)	186,464	(14.2)	229,354	(16.2)	174,895	(18.1)
≥ 70	145,177	(11.5)	202,603	(14.7)	170,503	(17.8)	202,874	(15.4)	267,978	(19.0)	216,910	(22.4)
Country of birth												
Sweden	957,012	(75.7)	1,174,452	(85.0)	862,926	(89.9)	994,846	(75.5)	1,188,984	(84.2)	857,466	(88.7)
Other Nordic countries	39,549	(3.1)	40,288	(2.9)	27,214	(2.8)	55,756	(4.2)	51,277	(3.6)	34,304	(3.6)
Other European countries	115,184	(9.1)	75,643	(5.5)	38,568	(4.0)	117,305	(8.9)	78,102	(5.5)	39,846	(4.1)
Middle Eastern countries	58,144	(4.6)	41,881	(3.0)	10,097	(1.1)	50,537	(3.8)	36,019	(2.6)	7,870	(0.8)
Rest of the world	95,154	(7.5)	49,726	(3.6)	20,649	(2.2)	99,108	(7.5)	57,623	(4.1)	27,052	(2.8)
Marital status												
Partner	554,643	(43.8)	617,495	(44.7)	434,587	(45.3)	553,125	(42.0)	617,306	(43.7)	433,254	(44.8)
Divorced	144,067	(11.4)	147,939	(10.7)	103,264	(10.8)	198,013	(15.0)	189,158	(13.4)	122,455	(12.7)

Single	538,417	(42.6)	576,605	(41.7)	388,420	(40.5)	462,975	(35.1)	462,158	(32.7)	290,770	(30.1)
Widowed	27,916	(2.2)	39,951	(2.9)	33,183	(3.5)	103,439	(7.9)	143,383	(10.2)	120,059	(12.4)
Education												
Primary	208,086	(16.5)	301,873	(21.8)	250,637	(26.1)	212,412	(16.1)	292,849	(20.7)	231,799	(24.0)
Secondary	526,005	(41.6)	659,870	(47.8)	497,659	(51.9)	505,959	(38.4)	605,839	(42.9)	455,680	(47.2)
Tertiary	498,022	(39.4)	399,521	(28.9)	197,663	(20.6)	569,828	(43.3)	492,440	(34.9)	267,593	(27.7)
Unknown	32,930	(2.6)	20,726	(1.5)	13,495	(1.4)	29,353	(2.2)	20,877	(1.5)	11,466	(1.2)
Employment status												
Employed	830,816	(65.7)	865,163	(62.6)	586,633	(61.1)	789,988	(60.0)	780,016	(55.2)	517,878	(53.6)
Unemployed	434,227	(34.3)	516,827	(37.4)	372,821	(38.9)	527,564	(40.0)	631,989	(44.8)	448,660	(46.4)
Disposable income quintile												
Highest	458,169	(36.2)	382,915	(27.7)	230,295	(24.0)	269,578	(20.5)	155,890	(11.0)	81,447	(8.4)
High	245,835	(19.4)	332,742	(24.1)	247,314	(25.8)	274,982	(20.9)	288,401	(20.4)	188,528	(19.5)
Middle	210,251	(16.6)	262,641	(19.0)	197,335	(20.6)	287,596	(21.8)	359,179	(25.4)	259,752	(26.9)
Low	173,456	(13.7)	240,228	(17.4)	181,319	(18.9)	285,420	(21.7)	391,876	(27.8)	286,238	(29.6)
Lowest	177,332	(14.0)	163,464	(11.8)	103,191	(10.8)	199,976	(15.2)	216,659	(15.3)	150,573	(15.6)
Total	1,265,043	(100)	1,381,990	(100)	959,454	(100)	1,317,552	(100)	1,412,005	(100)	966,538	(100)

Supplementary Table 3. Number of men by age, country of birth, sociodemographic characteristics, and neighborhood-level rurality.

	Neighborhood-level rurality							
	Urban	(%)	Sub-urban	(%)	Rural	(%)	Missing	(%)
Age								
20-29	525,198	(19.8)	40,469	(13.0)	71,504	(11.4)	1,633	(16.4)
30-39	483,481	(18.2)	47,997	(15.4)	83,303	(13.2)	2,253	(22.6)
40-49	484,866	(18.3)	61,140	(19.7)	115,953	(18.4)	2,352	(23.6)
50-59	407,615	(15.4)	51,311	(16.5)	122,253	(19.4)	2,039	(20.5)
60-69	392,094	(14.8)	58,477	(18.8)	133,126	(21.2)	1,140	(11.5)
≥ 70	362,906	(13.7)	51,818	(16.7)	103,026	(16.4)	533	(5.4)
Country of birth								
Sweden	2,120,903	(79.9)	281,205	(90.4)	586,458	(93.2)	5,824	(58.5)
Other Nordic countries	77,792	(2.9)	10,093	(3.2)	18,535	(3.0)	631	(6.3)
Other European countries	197,884	(7.5)	12,030	(3.9)	18,049	(2.9)	1,432	(14.4)
Middle Eastern countries	106,109	(4.0)	2,281	(0.7)	1,088	(0.2)	644	(6.5)
Rest of the world	153,472	(5.8)	5,603	(1.8)	5,035	(0.8)	1,419	(14.3)
Marital status								
Partner	1,144,582	(43.1)	159,129	(51.1)	301,935	(48.0)	1,079	(10.8)
Divorced	291,558	(11.0)	32,117	(10.3)	69,036	(11.0)	2,559	(25.7)
Single	1,148,727	(43.3)	109,479	(35.2)	239,023	(38.0)	6,213	(62.4)
Widowed	71,293	(2.7)	10,487	(3.4)	19,171	(3.1)	99	(1.0)
Education								
Primary	501,026	(18.9)	79,845	(25.7)	175,997	(28)	3,728	(37.5)

Secondary	1,192,104	(44.9)	157,806	(50.7)	329,908	(52.4)	3,716	(37.4)
Tertiary	908,770	(34.2)	69,530	(22.3)	115,532	(18.4)	1,374	(13.8)
Unknown	54,260	(2.0)	4,031	(1.3)	7,728	(1.2)	1,132	(11.4)
Employment status								
Employed	1,673,331	(63.0)	198,712	(63.9)	409,134	(65.0)	1,435	(14.4)
Unemployed	982,829	(37.0)	112,500	(36.2)	220,031	(35.0)	8,515	(85.6)
Disposable income quintile								
Highest	807,770	(30.4)	96,872	(31.1)	166,451	(26.5)	286	(2.9)
High	583,213	(22.0)	79,063	(25.4)	163,266	(26.0)	349	(3.5)
Middle	491,940	(18.5)	57,513	(18.5)	120,087	(19.1)	687	(6.9)
Low	435,308	(16.4)	49,904	(16.0)	107,920	(17.2)	1,871	(18.8)
Lowest	337,929	(12.7)	27,860	(9.0)	71,441	(11.4)	6,757	(67.9)
Total	2,656,160	(100)	311,212	(100)	629,165	(100)	9,950	(100)

Supplementary Table 4. Number of women by age, country of birth, sociodemographic characteristics, and neighborhood-level rurality.

	Neighborhood-level rurality							
	Urban	(%)	Sub-urban	(%)	Rural	(%)	Unknown	(%)
Age								
20-29	506,239	(18.1)	35992	(11.4)	64013	(11.1)	859	(23.1)
30-39	462,819	(16.5)	49872	(15.8)	80187	(13.9)	837	(22.6)
40-49	475,996	(17.0)	58,934	(18.7)	107060	(18.6)	686	(18.5)
50-59	412,898	(14.7)	49,223	(15.6)	111506	(19.4)	499	(13.4)
60-69	420,179	(15.0)	57765	(18.3)	112451	(19.5)	318	(8.6)
≥ 70	522,861	(18.7)	64131	(20.3)	100257	(17.4)	513	(13.8)
Country of birth								
Sweden	2,229,225	(79.6)	282,875	(89.5)	527,190	(91.6)	2,006	(54.0)
Other Nordic countries	108,738	(3.9)	11,635	(3.7)	20,782	(3.6)	182	(4.9)
Other European countries	206,023	(7.4)	11,671	(3.7)	16,966	(3.0)	593	(16.0)
Middle Eastern countries	91,585	(3.3)	1,721	(0.5)	784	(0.1)	336	(9.1)
Rest of the world	165,421	(5.9)	8,015	(2.5)	9,752	(1.7)	595	(16)
Marital status								
Partner	1,145,433	(40.9)	158,821	(50.3)	298,740	(51.9)	691	(18.6)
Divorced	413,687	(14.8)	36,425	(11.5)	58,514	(10.2)	1,000	(26.9)
Single	964,522	(34.4)	84,459	(26.7)	165,200	(28.7)	1,722	(46.4)
Widowed	277,350	(9.9)	36,212	(11.5)	53,020	(9.2)	299	(8.1)
Education								
Primary	540,011	(19.3)	73,222	(23.2)	122,574	(21.3)	1,253	(33.8)

Secondary	1,139,586	(40.7)	146,888	(46.5)	279,801	(48.6)	1,203	(32.4)
Tertiary	1,068,621	(38.2)	92,549	(29.3)	167,986	(29.2)	705	(19.0)
Unknown	52,774	(1.9)	3,258	(1.0)	5,113	(0.9)	551	(14.8)
Employment status								
Employed	1,563,353	(55.8)	178,890	(56.6)	345,128	(60.0)	511	(13.8)
Unemployed	1,237,639	(44.2)	137,027	(43.4)	230,346	(40.0)	3,201	(86.2)
Disposable income quintile								
Highest	412,125	(14.7)	34,952	(11.1)	59,693	(10.4)	145	(3.9)
High	567,314	(20.3)	66,492	(21.1)	117,922	(20.5)	183	(4.9)
Middle	669,651	(23.9)	82,850	(26.2)	153,683	(26.7)	343	(9.2)
Low	734,028	(26.2)	86,203	(27.3)	142,385	(24.7)	918	(24.7)
Lowest	417,874	(14.9)	45,420	(14.4)	101,791	(17.7)	2,123	(57.2)
Total	2,800,992	(100)	315,917	(100)	575,474	(100)	3,712	(100)

Supplementary Table 5. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] for men: the full results of multilevel Poisson regression analysis.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
<i>Fixed-effect part of the model</i>												
Age												
20-29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.85	[0.76,0.96]	0.86	[0.77,0.97]	0.87	[0.77,0.98]	0.86	[0.76,0.97]	0.86	[0.76,0.97]	1.43	[1.26,1.61]
40-49	1.14	[1.03,1.28]	1.13	[1.02,1.26]	1.14	[1.02,1.27]	1.12	[1.00,1.25]	1.12	[1.01,1.25]	2.00	[1.78,2.26]
50-59	1.34	[1.20,1.49]	1.31	[1.17,1.46]	1.30	[1.17,1.45]	1.28	[1.15,1.43]	1.28	[1.15,1.43]	2.14	[1.90,2.42]
60-69	1.14	[1.02,1.28]	1.09	[0.98,1.22]	1.09	[0.97,1.22]	1.08	[0.96,1.20]	1.07	[0.96,1.20]	1.43	[1.25,1.64]
≥ 70	1.57	[1.40,1.75]	1.49	[1.33,1.67]	1.48	[1.32,1.65]	1.48	[1.32,1.65]	1.47	[1.32,1.65]	1.37	[1.18,1.59]
Country of birth												
Sweden			Ref.		Ref.		Ref.		Ref.		Ref.	
Other Nordic countries			1.18	[0.99,1.39]	1.19	[1.00,1.40]	1.18	[1.00,1.40]	1.19	[1.00,1.40]	0.98	[0.83,1.16]
Other European countries			0.71	[0.60,0.82]	0.72	[0.61,0.84]	0.71	[0.61,0.83]	0.72	[0.62,0.84]	0.66	[0.56,0.77]
Middle Eastern countries			0.53	[0.41,0.68]	0.54	[0.42,0.70]	0.54	[0.42,0.70]	0.55	[0.43,0.71]	0.44	[0.34,0.57]
Rest of the world			0.46	[0.36,0.57]	0.47	[0.37,0.59]	0.46	[0.37,0.58]	0.47	[0.37,0.59]	0.39	[0.30,0.49]
Municipality-level rurality^a												
Urban					Ref.				Ref.		Ref.	
Sub-urban					1.19	[1.06,1.33]			1.16	[1.04,1.30]	1.04	[0.94,1.16]
Rural					1.28	[1.14,1.43]			1.23	[1.09,1.38]	1.06	[0.95,1.18]
Neighborhood-level rurality^b												

Urban	Ref.		Ref.			
Sub-urban	0.95	[0.84,1.08]	0.93	[0.82,1.05]	0.96	[0.85,1.09]
Rural	1.22	[1.12,1.33]	1.18	[1.08,1.28]	1.16	[1.07,1.27]
Unknown	3.34	[2.21,5.03]	3.33	[2.21,5.02]	1.38	[0.92,2.08]
Marital status						
Partner					Ref.	
Divorced					2.19	[1.98,2.41]
Single					1.99	[1.82,2.17]
Widowed					2.13	[1.81,2.52]
Education						
Tertiary					Ref.	
Primary					1.49	[1.35,1.64]
Secondary					1.32	[1.21,1.44]
Unknown					0.55	[0.38,0.79]
Employment status						
Employed					Ref.	
Unemployed					1.70	[1.54,1.87]
Disposable income quintile						
Highest					Ref.	
High					1.26	[1.13,1.41]
Middle					1.69	[1.51,1.89]
Low					2.06	[1.82,2.33]
Lowest					2.08	[1.81,2.40]
Random-effect part of the model						

Between-municipality variance^c Null=0.038(0.013)						
	0.031(0.012)	0.025(0.011)	0.021(0.009)	0.019(0.01)	0.019(0.008)	0.014(0.007)
Between-neighborhood variance^c Null=0.09(0.029)						
	0.093(0.029)	0.103(0.03)	0.100(0.029)	0.100(0.029)	0.097(0.029)	0.047(0.028)
Median rate ratios between municipalities Null=1.205						
	1.18	1.16	1.15	1.14	1.14	1.12
Median rate ratios between neighborhoods Null=1.332						
	1.34	1.36	1.35	1.35	1.35	1.23

^a We used the classification of municipality by the Swedish Association of Local Authorities and Regions as municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistics areas established by the Swedish government.

^c Standard error in parentheses.

Supplementary Table 6. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] for women: the full results of multilevel Poisson regression analysis.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
<i>Fixed-effect part of the model</i>												
Age												
20-29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.91	[0.76,1.10]	0.92	[0.76,1.11]	0.92	[0.76,1.11]	0.93	[0.77,1.12]	0.93	[0.77,1.12]	1.63	[1.35,1.99]
40-49	1.37	[1.16,1.62]	1.36	[1.15,1.61]	1.36	[1.15,1.61]	1.39	[1.17,1.64]	1.38	[1.17,1.64]	2.63	[2.19,3.16]
50-59	1.39	[1.17,1.65]	1.36	[1.15,1.62]	1.37	[1.15,1.62]	1.39	[1.17,1.65]	1.39	[1.17,1.65]	2.46	[2.03,2.98]
60-69	1.21	[1.01,1.44]	1.17	[0.98,1.39]	1.17	[0.98,1.39]	1.19	[1.00,1.42]	1.19	[0.99,1.42]	1.31	[1.06,1.62]
≥ 70	1.12	[0.94,1.34]	1.08	[0.90,1.29]	1.08	[0.90,1.29]	1.09	[0.91,1.30]	1.09	[0.91,1.30]	0.78	[0.62,0.99]
Country of birth												
Sweden			Ref.		Ref.		Ref.		Ref.		Ref.	
Other Nordic countries			1.17	[0.92,1.48]	1.16	[0.92,1.47]	1.16	[0.91,1.46]	1.15	[0.91,1.46]	0.98	[0.78,1.25]
Other European countries			1.01	[0.83,1.24]	1.01	[0.83,1.23]	0.99	[0.81,1.21]	0.99	[0.81,1.21]	0.82	[0.67,1.00]
Middle Eastern countries			0.41	[0.26,0.65]	0.41	[0.25,0.65]	0.39	[0.25,0.62]	0.39	[0.25,0.62]	0.29	[0.18,0.47]
Rest of the world			0.79	[0.61,1.02]	0.78	[0.61,1.01]	0.77	[0.60,0.99]	0.77	[0.59,0.99]	0.57	[0.44,0.74]
Municipality-level rurality^a												
Urban					Ref.				Ref.		Ref.	
Sub-urban					0.91	[0.79,1.06]			0.94	[0.81,1.10]	0.82	[0.72,0.92]
Rural					0.91	[0.78,1.07]			0.97	[0.83,1.13]	0.83	[0.72,0.95]
Neighborhood-level rurality^b												

Urban	Ref.		Ref.		Ref.	
Sub-urban	0.70	[0.57,0.86]	0.70	[0.57,0.86]	0.74	[0.60,0.91]
Rural	0.83	[0.72,0.96]	0.84	[0.72,0.97]	0.91	[0.78,1.06]
Unknown	4.81	[2.12,10.90]	4.81	[2.12,10.91]	2.11	[0.93,4.77]
Marital status						
Partner					Ref.	
Divorced					2.37	[2.06,2.73]
Single					2.29	[2.00,2.63]
Widowed					1.56	[1.26,1.94]
Education						
Tertiary					Ref.	
Primary					1.32	[1.14,1.53]
Secondary					1.14	[1.01,1.29]
Unknown					0.69	[0.43,1.12]
Employment status						
Employed					Ref.	
Unemployed					2.98	[2.57,3.46]
Disposable income quintile						
Highest					Ref.	
High					1.27	[1.02,1.58]
Middle					1.53	[1.23,1.89]
Low					1.75	[1.40,2.20]
Lowest					1.64	[1.28,2.12]
Random-effect part of the model						

Between-municipality variance^c Null=0.023(0.014)					
0.025(0.014)	0.029(0.015)	0.023(0.015)	0.023(0.014)	0.019(0.014)	0.000(0.000)
Between-neighborhood variance*** Null=0.138(0.065)					
0.143(0.065)	0.146(0.065)	0.151(0.066)	0.141(0.065)	0.144(0.065)	0.096(0.063)
Median rate ratios between municipalities Null=1.16					
1.16	1.18	1.15	1.15	1.14	1.00
Median rate ratios between neighborhoods Null=1.43					
1.43	1.44	1.45	1.43	1.44	1.34

^a We used the classification of municipality by the Swedish Association of Local Authorities and Regions as municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistics areas established by the Swedish government.

^c Standard error in parentheses.

Supplementary Table 7. Descriptive statistics of variables of the municipality-level rurality by Eurostat.

	Men			Women		
	Person-years	No. of suicides	Suicide rate ^a	Person-years	No. of suicides	Suicide rate ^a
Rurality DEGURBA (Municipality-level rurality)^b						
Cities	8,133,940	1,338	16.4	8,507,266	676	7.9
Towns and suburbs	6,394,578	1,152	18.0	6,559,714	479	7.3
Rural	6,217,268	1,321	21.2	6,222,948	457	7.3
Total	20,745,786	3,811	18.4	21,289,928	1,612	7.6

^a Suicide incidence per 100,000 person-years

^b The classification of municipality by Eurostat

Supplementary Table 8. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] by gender: the results of multilevel Poisson regression analysis.

	Men						Women					
	Model 3'		Model 5'		Model 6'		Model 3'		Model 5'		Model 6'	
	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
<i>Fixed-effect part of the model</i>												
Age												
20-29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.86	[0.76,0.97]	0.86	[0.76,0.97]	1.42	[1.26,1.61]	0.92	[0.76,1.11]	0.93	[0.77,1.12]	1.64	[1.35,1.99]
40-49	1.13	[1.01,1.26]	1.12	[1.00,1.25]	2.00	[1.78,2.25]	1.37	[1.16,1.62]	1.39	[1.17,1.64]	2.64	[2.19,3.17]
50-59	1.30	[1.16,1.44]	1.28	[1.15,1.43]	2.14	[1.90,2.41]	1.37	[1.15,1.63]	1.39	[1.17,1.65]	2.46	[2.03,2.98]
60-69	1.08	[0.96,1.21]	1.07	[0.95,1.20]	1.43	[1.24,1.64]	1.17	[0.98,1.40]	1.19	[1.00,1.42]	1.31	[1.06,1.62]
≥ 70	1.47	[1.32,1.65]	1.47	[1.31,1.64]	1.36	[1.17,1.59]	1.08	[0.90,1.30]	1.09	[0.91,1.30]	0.78	[0.62,0.99]
Country of birth												
Sweden	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Other Nordic countries	1.18	[1.00,1.40]	1.18	[1.00,1.40]	0.98	[0.83,1.16]	1.16	[0.92,1.47]	1.16	[0.91,1.47]	0.99	[0.78,1.26]
Other European countries	0.72	[0.61,0.84]	0.72	[0.62,0.84]	0.66	[0.56,0.77]	1.01	[0.83,1.23]	0.99	[0.81,1.21]	0.82	[0.67,1.01]
Middle Eastern countries	0.54	[0.42,0.70]	0.55	[0.43,0.71]	0.45	[0.35,0.58]	0.4	[0.25,0.65]	0.39	[0.25,0.62]	0.29	[0.18,0.47]
Rest of the world	0.47	[0.37,0.59]	0.47	[0.37,0.59]	0.39	[0.31,0.49]	0.78	[0.61,1.01]	0.77	[0.59,0.99]	0.57	[0.44,0.74]
Municipality-level rurality (DEGURBA)^a												
Urban	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
Sub-urban	1.07	[0.95,1.20]	1.05	[0.94,1.18]	1.01	[0.91,1.12]	0.94	[0.80,1.09]	0.96	[0.83,1.12]	0.93	[0.80,1.07]
Rural	1.24	[1.11,1.38]	1.19	[1.06,1.33]	1.10	[0.99,1.22]	0.92	[0.79,1.07]	1.00	[0.86,1.17]	0.95	[0.81,1.11]

Neighborhood-level rurality^b

Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.92	[0.81,1.04]	0.95	[0.84,1.07]	0.69	[0.56,0.86]	0.73	[0.59,0.90]
Rural	1.17	[1.07,1.28]	1.14	[1.05,1.25]	0.83	[0.71,0.96]	0.89	[0.76,1.04]
Unknown	3.33	[2.21,5.02]	1.38	[0.92,2.08]	4.81	[2.12,10.89]	2.11	[0.94,4.77]

Marital status

Partner			Ref.				Ref.	
Divorced			2.19	[1.98,2.41]			2.36	[2.05,2.73]
Single			1.99	[1.82,2.17]			2.28	[1.98,2.62]
Widowed			2.14	[1.81,2.53]			1.55	[1.25,1.93]

Education

Tertiary			Ref.				Ref.	
Primary			1.48	[1.34,1.64]			1.32	[1.14,1.53]
Secondary			1.31	[1.20,1.43]			1.15	[1.02,1.30]
Unknown			0.55	[0.38,0.79]			0.70	[0.43,1.13]

Employment status

Employed			Ref.				Ref.	
Unemployed			1.70	[1.54,1.87]			2.98	[2.57,3.46]

Disposable income quintile

Highest			Ref.				Ref.	
High			1.26	[1.13,1.41]			1.25	[1.00,1.56]
Middle			1.69	[1.51,1.89]			1.50	[1.21,1.86]
Low			2.06	[1.82,2.33]			1.72	[1.37,2.16]
Lowest			2.08	[1.80,2.39]			1.62	[1.26,2.08]

Random-effect part of the model

Between-municipality variance^c

0.02(0.009) 0.018(0.009) 0.013 (0.007) 0.026(0.015) 0.021(0.014) 0.018 (0.013)

Between-neighborhood variance^c

0.100(0.029) 0.097(0.029) 0.046 (0.028) 0.149(0.065) 0.142(0.065) 0.083 (0.064)

Median rate ratios between municipalities

1.15 1.14 1.12 1.17 1.15 1.14

Median rate ratios between neighborhoods

1.35 1.35 1.23 1.45 1.43 1.32

^a We used the classification of municipality by Eurostat as municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistics areas established by the Swedish government.

^c Standard error in parentheses.

Supplementary Table 9. Suicide Hazard Ratios (HR) [95% Confidence Intervals] for men: the results of parametric multilevel survival analyses.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
<i>Fixed-effect part of the model</i>												
Age												
20-29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.85	[0.76,0.96]	0.86	[0.77,0.97]	0.87	[0.77,0.98]	0.86	[0.76,0.97]	0.86	[0.76,0.97]	1.43	[1.26,1.62]
40-49	1.14	[1.02,1.27]	1.13	[1.02,1.26]	1.13	[1.02,1.27]	1.12	[1.00,1.25]	1.12	[1.01,1.25]	2.01	[1.78,2.26]
50-59	1.34	[1.20,1.49]	1.31	[1.17,1.46]	1.30	[1.17,1.45]	1.28	[1.15,1.43]	1.28	[1.15,1.43]	2.15	[1.90,2.42]
60-69	1.15	[1.02,1.28]	1.09	[0.98,1.23]	1.09	[0.97,1.22]	1.08	[0.96,1.21]	1.08	[0.96,1.21]	1.44	[1.25,1.65]
≥ 70	1.60	[1.43,1.78]	1.52	[1.36,1.70]	1.50	[1.34,1.68]	1.50	[1.34,1.68]	1.50	[1.34,1.67]	1.39	[1.20,1.62]
Country of birth												
Sweden			Ref.		Ref.		Ref.		Ref.		Ref.	
Other Nordic countries			1.18	[1.00,1.40]	1.19	[1.01,1.41]	1.18	[1.00,1.40]	1.19	[1.01,1.41]	0.98	[0.83,1.17]
Other European countries			0.71	[0.61,0.83]	0.72	[0.62,0.84]	0.72	[0.61,0.84]	0.72	[0.62,0.85]	0.66	[0.57,0.77]
Middle Eastern countries			0.53	[0.41,0.68]	0.54	[0.42,0.70]	0.54	[0.42,0.70]	0.55	[0.43,0.71]	0.44	[0.34,0.57]
Rest of the world			0.46	[0.36,0.58]	0.47	[0.37,0.59]	0.46	[0.37,0.58]	0.47	[0.37,0.59]	0.39	[0.31,0.49]
Municipality-level rurality^a												
Urban					Ref.				Ref.		Ref.	
Sub-urban					1.19	[1.06,1.33]			1.16	[1.04,1.30]	1.04	[0.94,1.16]
Rural					1.28	[1.14,1.43]			1.23	[1.10,1.38]	1.06	[0.95,1.18]
Neighborhood-level rurality^b												
Urban							Ref.		Ref.		Ref.	

Sub-urban	0.95	[0.84,1.08]	0.93	[0.82,1.05]	0.96	[0.85,1.09]
Rural	1.22	[1.12,1.33]	1.17	[1.08,1.28]	1.16	[1.07,1.27]
Unknown	3.40	[2.25,5.12]	3.39	[2.25,5.11]	1.40	[0.93,2.10]

Marital status

Partner					Ref.	
Divorced					2.19	[1.99,2.42]
Single					1.99	[1.82,2.17]
Widowed					2.17	[1.83,2.56]

Education

Tertiary					Ref.	
Primary					1.49	[1.35,1.65]
Secondary					1.32	[1.21,1.44]
Unknown					0.55	[0.38,0.80]

Employment status

Employed					Ref.	
Unemployed					1.70	[1.54,1.87]

Disposable income quintile

Highest					Ref.	
High					1.26	[1.13,1.41]
Middle					1.69	[1.51,1.89]
Low					2.07	[1.83,2.34]
Lowest					2.09	[1.81,2.40]

Random-effect part of the model

Between-municipality variance^c Null=0.038(0.013)

0.031(0.012)	0.025(0.011)	0.021(0.009)	0.019(0.009)	0.019(0.008)	0.014(0.007)
Between-neighborhood variance^c Null=0.09(0.029)					
0.093(0.029)	0.103(0.03)	0.101(0.029)	0.097(0.029)	0.097(0.029)	0.047(0.028)

^a We used the classification of municipality by the Swedish Association of Local Authorities and Regions as municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistics areas established by the Swedish government.

^c Standard error in parentheses.

Supplementary Table 10. Suicide Hazard Ratios (HR) [95% Confidence Intervals] for women: the results of parametric multilevel survival analyses.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
<i>Fixed-effect part of the model</i>												
Age												
20-29	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
30-39	0.91	[0.76,1.10]	0.92	[0.76,1.11]	0.92	[0.76,1.10]	0.93	[0.77,1.12]	0.93	[0.77,1.12]	1.64	[1.35,1.99]
40-49	1.37	[1.16,1.62]	1.36	[1.15,1.61]	1.36	[1.15,1.61]	1.38	[1.17,1.64]	1.38	[1.17,1.63]	2.63	[2.19,3.16]
50-59	1.39	[1.17,1.65]	1.36	[1.15,1.62]	1.36	[1.15,1.62]	1.39	[1.17,1.65]	1.39	[1.17,1.65]	2.46	[2.03,2.98]
60-69	1.21	[1.01,1.44]	1.17	[0.98,1.39]	1.17	[0.98,1.39]	1.19	[1.00,1.42]	1.19	[0.99,1.42]	1.31	[1.06,1.62]
≥ 70	1.14	[0.95,1.36]	1.09	[0.91,1.31]	1.10	[0.92,1.31]	1.10	[0.92,1.32]	1.11	[0.92,1.32]	0.79	[0.63,1.00]
Country of birth												
Sweden			Ref.		Ref.		Ref.		Ref.		Ref.	
Other Nordic countries			1.17	[0.92,1.48]	1.16	[0.92,1.48]	1.16	[0.91,1.47]	1.16	[0.91,1.47]	0.99	[0.78,1.25]
Other European countries			1.02	[0.83,1.24]	1.01	[0.83,1.23]	0.99	[0.81,1.21]	0.99	[0.81,1.21]	0.82	[0.67,1.00]
Middle Eastern countries			0.41	[0.26,0.65]	0.41	[0.25,0.65]	0.39	[0.25,0.63]	0.39	[0.25,0.63]	0.29	[0.18,0.47]
Rest of the world			0.79	[0.61,1.02]	0.79	[0.61,1.01]	0.77	[0.60,0.99]	0.77	[0.60,0.99]	0.57	[0.44,0.74]
Municipality-level rurality^a												
Urban					Ref.				Ref.		Ref.	
Sub-urban					0.91	[0.79,1.06]			0.94	[0.81,1.10]	0.82	[0.72,0.92]
Rural					0.91	[0.78,1.07]			0.97	[0.83,1.14]	0.83	[0.72,0.95]
Neighborhood-level rurality^b												

Urban	Ref.		Ref.		Ref.	
Sub-urban	0.70	[0.57,0.86]	0.70	[0.57,0.86]	0.74	[0.60,0.91]
Rural	0.83	[0.72,0.96]	0.84	[0.72,0.97]	0.91	[0.78,1.06]
Unknown	4.95	[2.18,11.20]	4.95	[2.18,11.21]	2.15	[0.95,4.87]
Marital status						
Partner					Ref.	
Divorced					2.38	[2.06,2.74]
Single					2.30	[2.00,2.64]
Widowed					1.58	[1.27,1.96]
Education						
Tertiary					Ref.	
Primary					1.32	[1.14,1.53]
Secondary					1.14	[1.01,1.29]
Unknown					0.70	[0.43,1.13]
Employment status						
Employed					Ref.	
Unemployed					2.99	[2.57,3.47]
Disposable income quintile						
Highest					Ref.	
High					1.27	[1.02,1.58]
Middle					1.53	[1.23,1.89]
Low					1.76	[1.40,2.21]
Lowest					1.65	[1.28,2.12]
<i>Random-effect part of the model</i>						

Between-municipality variance^c Null=0.023(0.014)

0.025(0.014) 0.029(0.015) 0.023(0.015) 0.023(0.014) 0.019(0.014) 0.000(0.000)

Between-neighborhood variance^c Null=0.139(0.065)

0.143(0.065) 0.146(0.065) 0.151(0.066) 0.141(0.065) 0.144(0.065) 0.097(0.063)

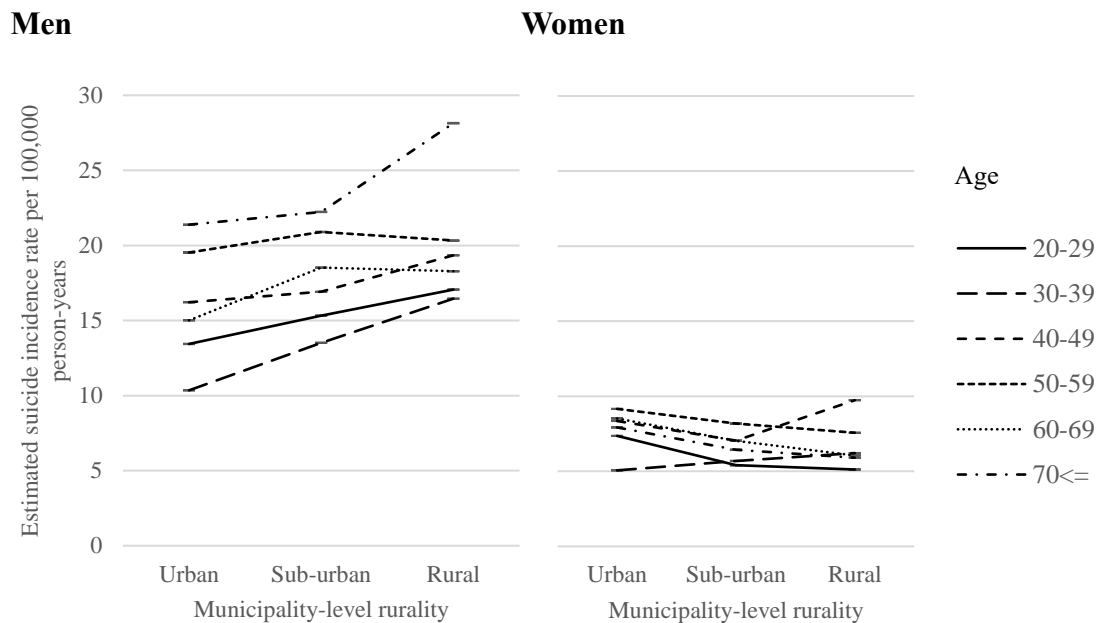
^a We used the classification of municipality by the Swedish Association of Local Authorities and Regions as municipality-level rurality.

^b For neighborhood-level rurality we used the DeSO unit, which denotes demographic statistics areas established by the Swedish government.

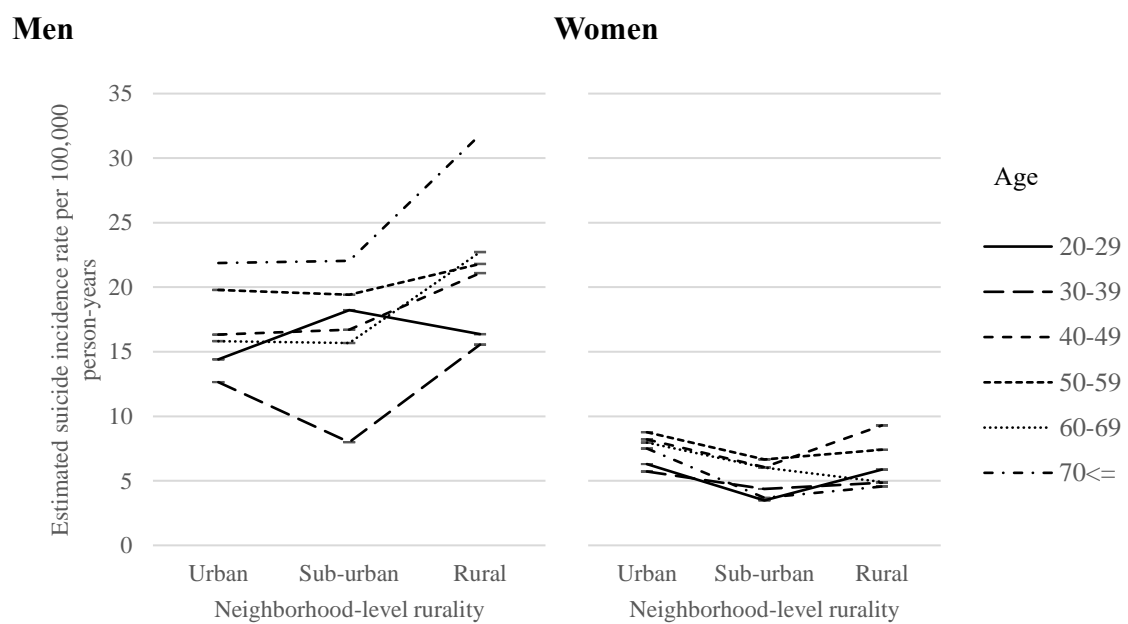
^c Standard error in parentheses.

Supplementary Figure 1. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by rurality, age, and gender. The estimates were derived from three-level multilevel Poisson regression adjusted for: a) country of birth and neighborhood-level rurality; and b) country of birth and municipality-level rurality.

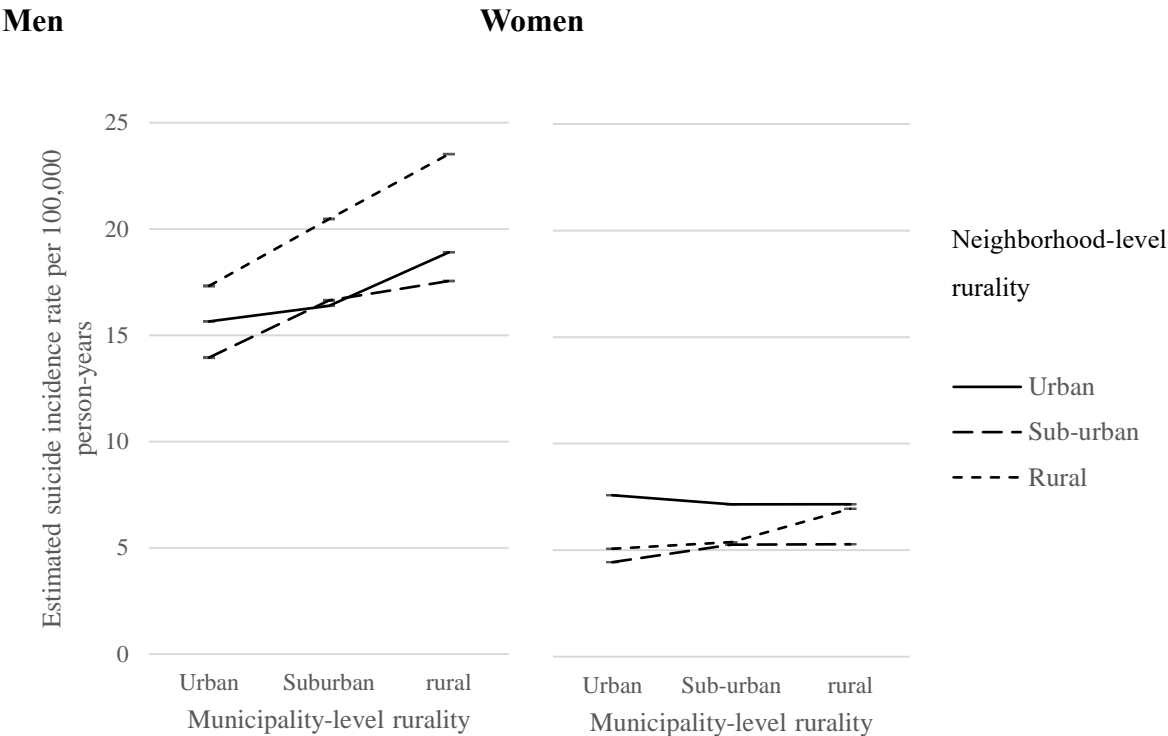
a) Municipality-level rurality



b) Neighborhood-level rurality

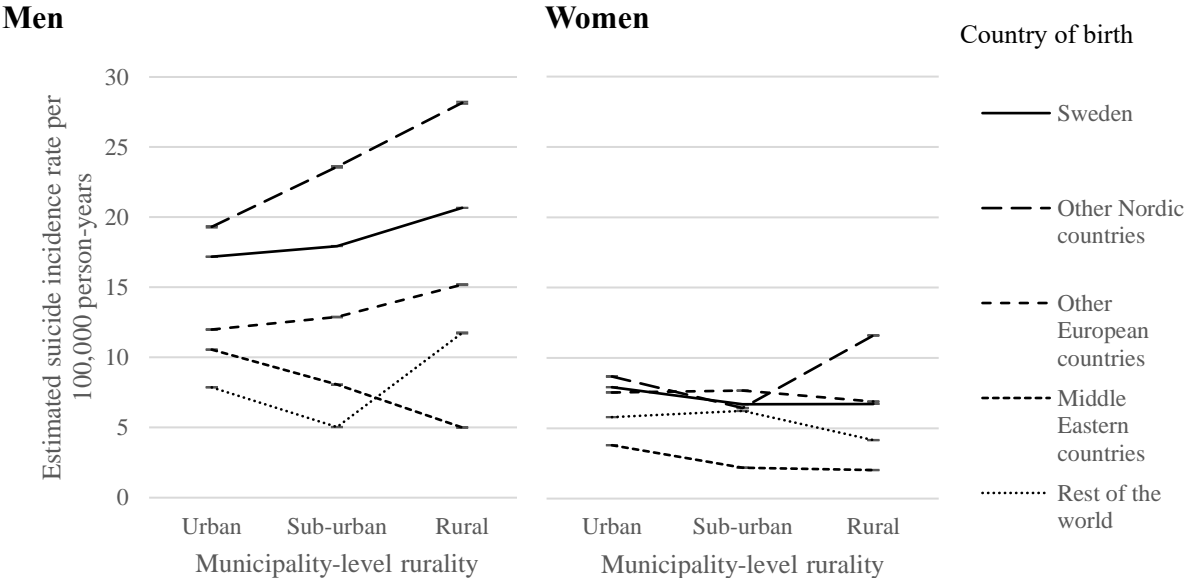


Supplementary Figure 2. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide. The estimates were derived from three-level multilevel Poisson regression adjusted for age as well as country of birth, municipality-level rurality, and neighborhood-level rurality. The classification of municipality by Eurostat as municipality-level rurality was used instead of that by the Swedish Association of Local Authorities and Regions.

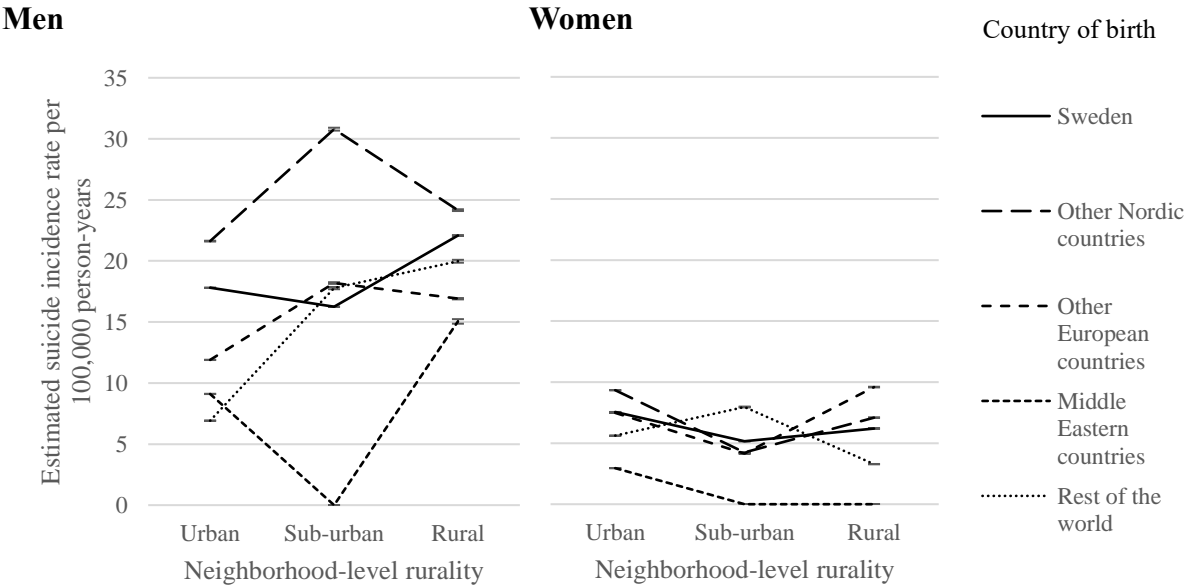


Supplementary Figure 3. Estimated suicide incidence rate per 100,000 person-years with 95% confidence intervals by rurality, country of birth, and gender. The estimates were derived from three-level multilevel Poisson regression adjusted for: a) age and neighborhood-level rurality; and b) age and municipality-level rurality. The classification of municipality by Eurostat as municipality-level rurality was used instead of that by the Swedish Association of Local Authorities and Regions.

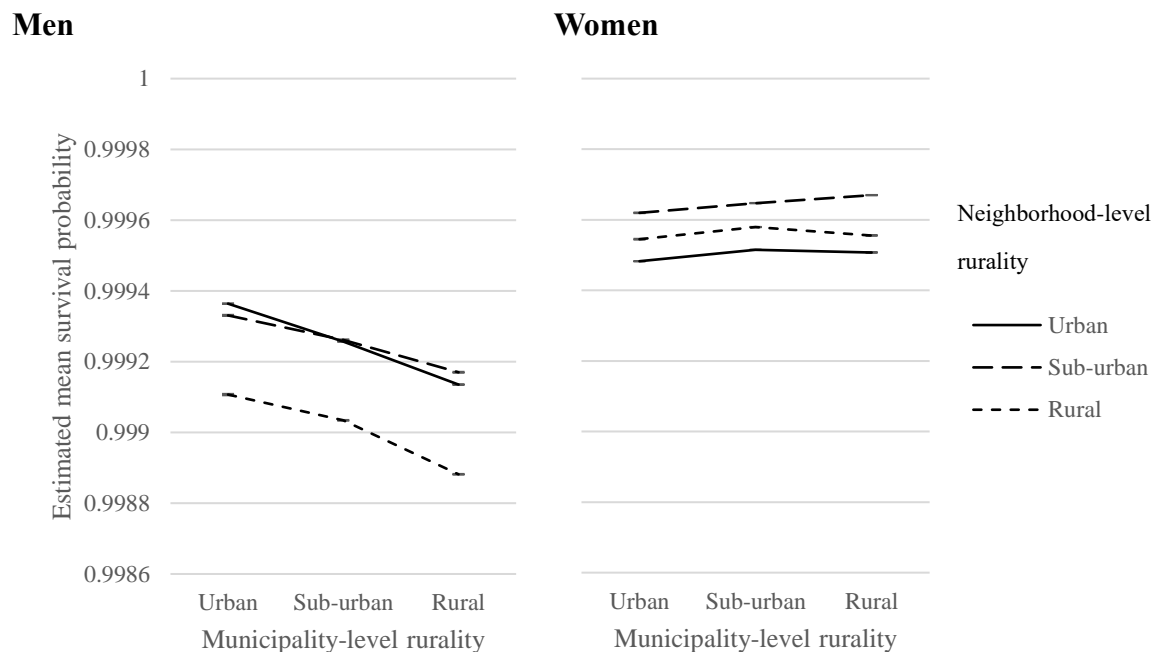
a) Municipality-level rurality



b) Neighborhood-level rurality

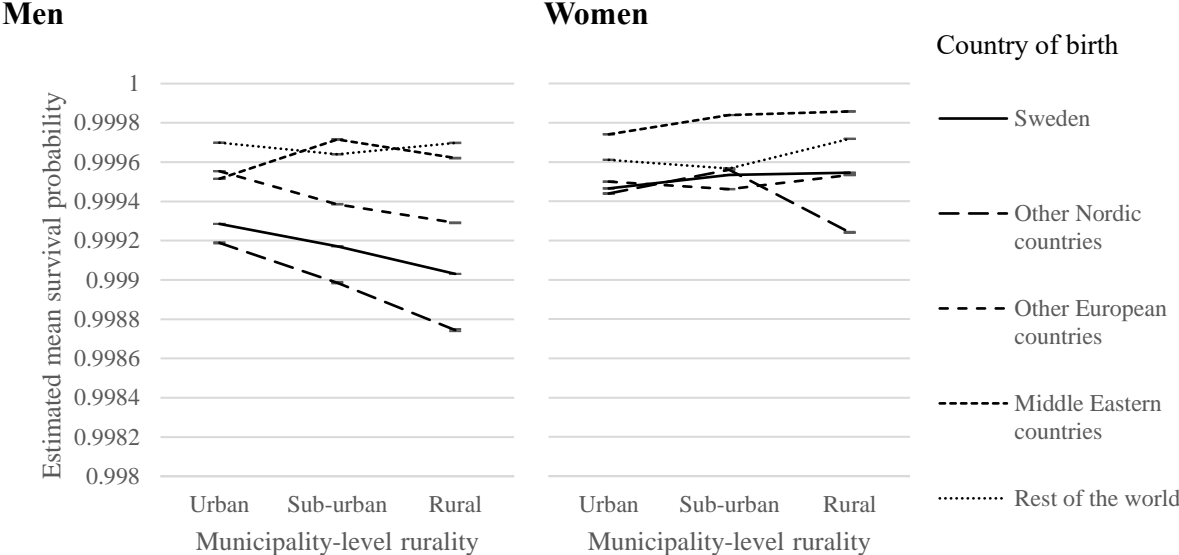


Supplementary Figure 4. Estimated survival probability with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide. The estimates were derived from three-level multilevel survival analyses adjusted for age as well as country of birth, municipality-level rurality, and neighborhood-level rurality.

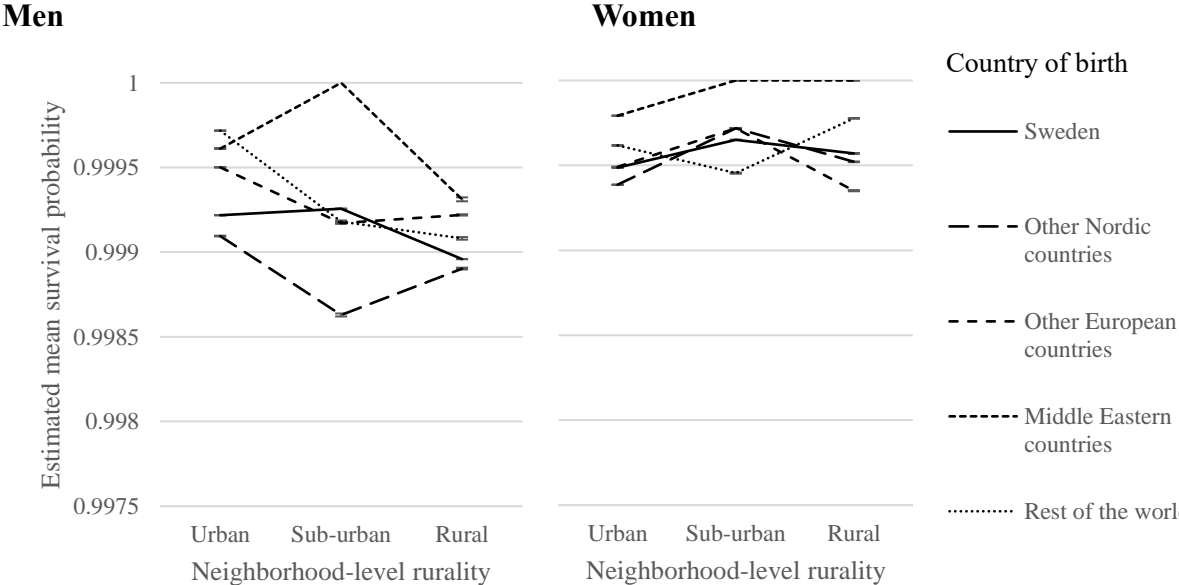


Supplementary Figure 5. Estimated survival probability with 95% confidence intervals by rurality, country of birth, and gender. The estimates were derived from three-level multilevel survival analyses adjusted for: a) age and neighborhood-level rurality; and b) age and municipality-level rurality.

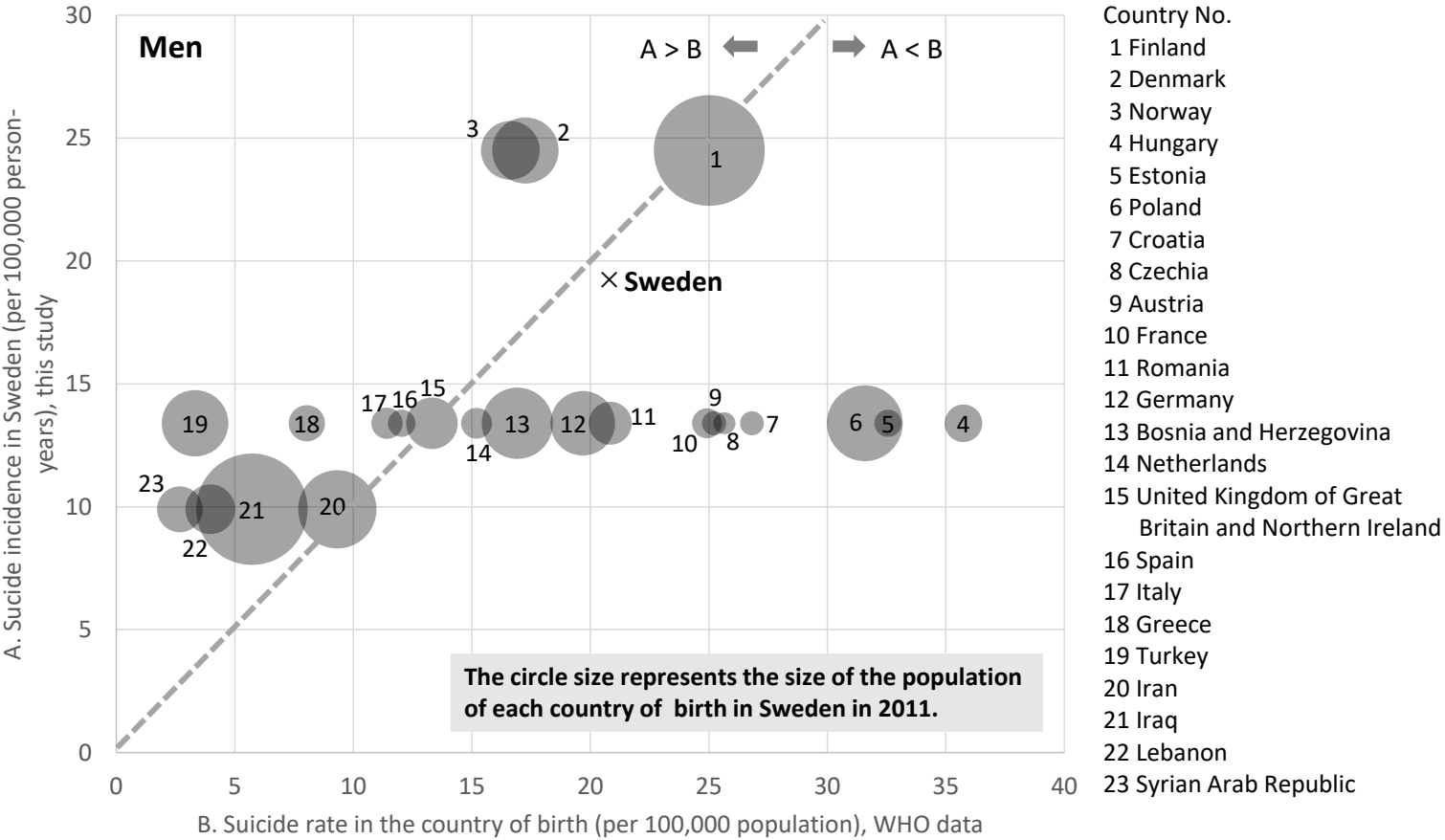
a) Municipality-level rurality



b) Neighborhood-level rurality



Supplementary Figure 6. Male suicide incidence rates by country of birth in Sweden and the male suicide rate in each country. The X-axis is the suicide incidence rate for each country of birth in Sweden, obtained in this study (A, shown in Table 1). The Y-axis is the crude suicide rate in each country of birth averaged over 2011–2016, estimated by the World Health Organization (B). The circle size represents the size of the population of each country of birth in Sweden in 2011. The country number refers to the countries listed in the right-hand panel. The dotted line indicates that A and B are equal. The rest of the world category in the study and Yugoslavia are not included in the figure.

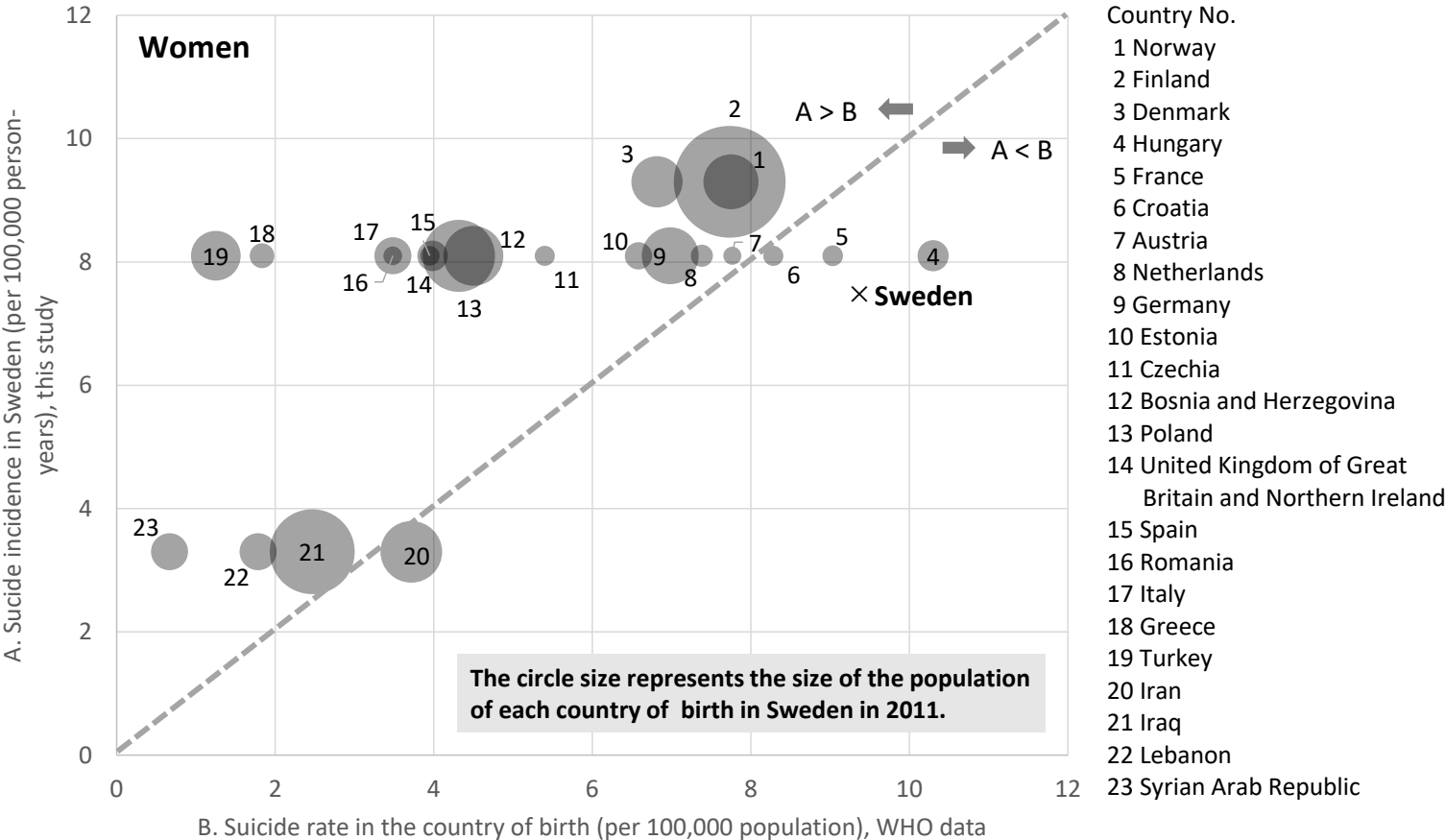


Source:

World Health Organization. Global Health Observatory data repository. Suicide rate estimates, crude. 2011 – 2016. [cited 22 Dec 2021].

Available: <https://apps.who.int/gho/data/view.main.MHSUICIDEv>

Supplementary Figure 7. Female suicide incidence rates by country of birth in Sweden and the female suicide rate in each country. The X-axis is the suicide incidence rate for each country of birth in Sweden, obtained in this study (A, shown in Table 1). The Y-axis is the crude suicide rate in each country of birth averaged over 2011–2016, estimated by the World Health Organization (B). The circle size represents the size of the population of each country of birth in Sweden in 2011. The country number refers to the countries listed in the right-hand panel. The dotted line indicates that A and B are equal. The rest of the world category in the study and Yugoslavia are not included in the figure.



Source:

World Health Organization. Global Health Observatory data repository. Suicide rate estimates, crude. 2011 – 2016. [cited 22 Dec 2021].

Available: <https://apps.who.int/gho/data/view.main.MHSUICIDEv>

Supplemental materials for Study 2

Supplementary Table 11. Population by country of birth and gender in Sweden (top 10 countries of birth excepting those born in Sweden).

Supplementary Table 12. Suicide rates by country of birth and rurality among Swedish men in all cohorts.

Supplementary Table 13. Suicide rates by country of birth and rurality among Swedish women in all cohorts.

Supplementary Table 14. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: cross-level interaction between country of birth and municipality-level rurality on suicide.

Supplementary Table 15. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: cross-level interaction between country of birth and neighborhood-level rurality on suicide.

Supplementary Table 16. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of women: cross-level interaction between country of birth and municipality-level rurality on suicide.

Supplementary Table 17. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of women: cross-level interaction between country of birth and neighborhood-level rurality on suicide.

Supplementary Table 18. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] by gender: the results of multilevel Poisson regression analyses in all cohorts.

Supplementary Table 19. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 1991-1995 Swedish registry-based cohort data.

Supplementary Table 20. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 1996-2000 Swedish registry-based cohort data.

Supplementary Table 21. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 2001-2005 Swedish registry-based cohort data.

Supplementary Table 22. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 2006-2011 Swedish registry-based cohort data.

Supplementary Table 23. Number of men and women by country of birth, municipality-level rurality and neighborhood-level rurality.

Supplementary Table 24. Health equity policies and suicide prevention programs in Sweden between 1991 and 2015.

Supplementary Figure 8. Flow chart of the study population. We excluded the data of individuals (a) that were duplicated, (b) who were missing an individual ID number, and (c) who were missing residential information.

Supplementary Figure 9. Secular trends in health inequality measures of suicide incidence per 100,000 person-years with 95% confidence intervals between urban and rural municipalities by country of birth and gender.

Supplementary Figure 10. Secular trends in health inequality measures of suicide incidence per 100,000 person-years with 95% confidence intervals between urban and rural neighborhoods by country of birth and gender.

Supplementary Figure 11. Secular trends in estimated suicide incidence per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide.

Supplementary Table 11. Population by country of birth and gender in Sweden (top 10 countries of birth excepting those born in Sweden).

Order	1991		1996		2001		2006		2011	
	Country of birth	n	Country of birth	n	Country of birth	n	Country of birth	n	Country of birth	n
Men										
1	Finland	91,780	Finland	85,580	Finland	80,431	Finland	74,155	Iraq	67,851
2	Iran	25,450	Yugoslavia	35,894	Yugoslavia	37,423	Iraq	45,958	Finland	67,184
3	Yugoslavia	23,373	Iran	27,460	Iraq	31,221	Yugoslavia	37,485	Yugoslavia	35,434
4	Denmark	22,638	B&H*	23,068	Iran	27,955	Iran	29,584	Iran	33,564
5	Norway	21,557	Denmark	20,823	B&H*	25,839	B&H*	27,354	Poland	31,449
6	Germany	15,969	Norway	17,776	Denmark	20,299	Denmark	23,695	B&H*	27,751
7	Turkey	14,162	Iraq	17,165	Norway	18,075	Germany	19,835	Turkey	24,182
8	Chile	14,096	Germany	15,799	Germany	17,379	Poland	19,788	Denmark	24,007
9	Poland	13,370	Turkey	15,741	Turkey	17,021	Turkey	19,746	Germany	22,722
10	Lebanon	10,646	Poland	13,715	Poland	13,951	Norway	19,345	Somalia	20,265
Women										
1	Finland	122,690	Finland	117,791	Finland	113,034	Finland	106,751	Finland	99,539
2	Norway	29,236	Yugoslavia	34,009	Yugoslavia	35,851	Iraq	36,869	Iraq	57,648
3	Poland	23,500	Norway	26,057	Poland	26,555	Yugoslavia	36,186	Poland	41,416
4	Yugoslavia	21,570	Poland	25,807	B&H*	26,359	Poland	31,955	Yugoslavia	34,616
5	Germany	20,471	B&H*	23,696	Norway	25,339	B&H*	28,111	Iran	30,264
6	Denmark	20,326	Iran	21,743	Iraq	24,475	Iran	26,163	B&H*	28,539
7	Iran	18,166	Germany	20,137	Iran	23,889	Norway	25,382	Thailand	26,261
8	Chile	13,863	Denmark	18,969	Germany	21,478	Germany	23,209	Germany	25,720
9	Turkey	12,683	Turkey	14,484	Denmark	18,571	Denmark	20,749	Norway	24,154
10	Lebanon	7,986	Chile	13,435	Turkey	15,432	Turkey	17,361	Denmark	20,944

*Bosnia and Herzegovina.

Source:

Statistics Sweden. Statistical Yearbook of Sweden. 1993.

Statistics Sweden. Statistical Yearbook of Sweden. 1998.

Statistics Sweden. Population by country of birth, age and sex. Year 2000 – 2020. [cited 22 Dec 2021]. Available:

<https://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/>

Supplementary Table 12. Suicide rates by country of birth and rurality among Swedish men in all cohorts.

	1991 cohort			1996 cohort			2001 cohort		
	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a
Age									
20-29	3,079,620	502	16.3	2,946,049	404	13.7	2,747,045	351	12.8
30-39	2,905,145	591	20.3	3,087,662	546	17.7	3,191,910	474	14.9
40-49	3,200,750	800	25.0	3,043,619	627	20.6	2,920,068	617	21.1
50-59	2,189,365	544	24.8	2,747,536	629	22.9	3,091,408	636	20.6
60-69	1,913,571	428	22.4	1,832,589	390	21.3	1,972,064	429	21.8
≥ 70	1,888,591	682	36.1	1,992,898	604	30.3	2,017,484	554	27.5
Country of birth									
Sweden	13,596,611	3,193	23.5	13,838,075	2,850	20.6	13,931,785	2,702	19.4
European countries	1,151,504	292	25.4	1,251,269	270	21.6	1,297,959	279	21.5
Non-European countries	428,927	62	14.5	561,009	80	14.3	710,235	80	11.3
Municipality-level rurality^b									
Urban	9,060,608	2,025	22.3	9,663,104	1,847	19.1	10,180,748	1,826	17.9
Sub-urban	3,835,886	889	23.2	3,734,887	784	21.0	3,584,724	750	20.9
Rural	2,280,548	633	27.8	2,252,362	569	25.3	2,174,507	485	22.3
Neighborhood-level rurality^c									
Urban	10,801,717	2,443	22.6	11,246,791	2,213	19.7	11,561,147	2,097	18.1
Sub-urban	1,409,033	325	23.1	1,421,263	264	18.6	1,409,497	278	19.7

Rural	2,966,292	779	26.3	2,982,299	723	24.2	2,969,335	686	23.1
Total	15,177,042	3,547	23.4	15,650,353	3,200	20.4	15,939,979	3,061	19.2

	2006 cohort			2011 cohort		
	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a
Age						
20-29	2,724,577	423	15.5	3,121,208	481	15.4
30-39	3,076,192	404	13.1	3,016,552	379	12.6
40-49	3,102,007	616	19.9	3,272,562	549	16.8
50-59	2,944,189	674	22.9	2,866,578	571	19.9
60-69	2,500,802	471	18.8	2,838,511	495	17.4
≥ 70	2,064,113	508	24.6	2,270,238	531	23.4
Country of birth						
Sweden	14,080,226	2,705	19.2	14,511,267	2,654	18.3
European countries	1,390,553	273	19.6	1,572,962	245	15.6
Non-European countries	941,101	118	12.5	1,301,420	107	8.2
Municipality-level rurality^b						
Urban	10,611,965	1,849	17.4	11,468,675	1,862	16.2
Sub-urban	3,634,887	744	20.5	3,738,519	682	18.2
Rural	2,165,028	503	23.2	2,178,455	462	21.2
Neighborhood-level rurality^c						
Urban	11,964,639	2,101	17.6	12,825,500	2,084	16.2

Sub-urban	1,443,224	260	18.0	1,506,110	254	16.9
Rural	3,004,017	735	24.5	3,054,039	668	21.9
Total	16,411,880	3,096	18.9	17,385,649	3,006	17.3

^a Suicide incidence per 100,000 person-years

^b We used population density as a marker of municipality-level rurality.

^c For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 13. Suicide rates by country of birth and rurality among Swedish women in all cohorts.

	1991 cohort			1996 cohort			2001 cohort		
	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a
Age									
20-29	2,924,601	168	5.7	2,828,930	149	5.3	2,649,070	153	5.8
30-39	2,789,951	233	8.4	2,957,259	201	6.8	3,064,836	189	6.2
40-49	3,095,627	343	11.1	2,976,091	269	9.0	2,848,539	220	7.7
50-59	2,196,937	247	11.2	2,702,688	260	9.6	3,051,273	275	9.0
60-69	2,152,762	224	10.4	2,029,864	160	7.9	2,085,954	174	8.3
≥ 70	2,834,351	334	11.8	2,996,120	257	8.6	2,995,807	236	7.9
Country of birth									
Sweden	14,271,104	1,355	9.5	14,463,389	1,084	7.5	14,436,917	1,043	7.2
European countries	1,367,087	172	12.6	1,506,022	185	12.3	1,555,733	157	10.1
Non-European countries	356,038	22	6.2	521,541	27	5.2	702,829	47	6.7
Municipality-level rurality^b									
Urban	9,790,458	1,045	10.7	10,392,645	917	8.8	10,844,619	877	8.1
Sub-urban	3,922,492	315	8.0	3,834,041	246	6.4	3,667,541	249	6.8
Rural	2,281,279	189	8.3	2,264,266	133	5.9	2,183,319	121	5.5
Neighborhood-level rurality^c									
Urban	11,826,243	1,247	10.5	12,270,981	1,070	8.7	12,497,396	1,014	8.1
Sub-urban	1,433,760	112	7.8	1,458,841	98	6.7	1,451,391	80	5.5

Rural	2,734,226	190	6.9	2,761,130	128	4.6	2,746,692	153	5.6
Total	15,994,229	1,549	9.7	16,490,952	1,296	7.9	16,695,479	1,247	7.5

	2006 cohort			2011 cohort		
	Person-year	No. of suicide	Suicide rate ^a	Person-year	No. of suicide	Suicide rate ^a
Age						
20-29	2,608,499	136	5.2	2,972,244	185	6.2
30-39	2,983,607	175	5.9	2,922,641	167	5.7
40-49	3,014,244	241	8.0	3,185,678	278	8.7
50-59	2,932,064	237	8.1	2,842,003	252	8.9
60-69	2,552,928	192	7.5	2,897,752	214	7.4
≥ 70	2,958,202	183	6.2	3,045,332	215	7.1
Country of birth						
Sweden	14,449,987	994	6.9	15,404,059	1,096	7.1
European countries	1,648,381	135	8.2	1,788,760	149	8.3
Non-European countries	951,176	35	3.7	1,336,754	66	4.9
Municipality-level rurality^b						
Urban	11,190,992	788	7.0	11,934,359	898	7.5
Sub-urban	3,703,977	246	6.6	3,781,003	257	6.8
Rural	2,154,575	130	6.0	2,150,288	156	7.3
Neighborhood-level rurality^c						
Urban	12,801,255	916	7.2	13,534,632	1,036	7.7
Sub-urban	1,478,712	96	6.5	1,526,990	83	5.4

Rural	2,769,577	152	5.5	2,804,028	192	6.8
Total	17,049,544	1,164	6.8	17,865,650	1,311	7.3

^a Suicide incidence per 100,000 person-years

^b We used population density as a marker of municipality-level rurality.

^c For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 14. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: cross-level interaction between country of birth and municipality-level rurality on suicide.

	1991 cohort		1996 cohort		2001 cohort		2006 cohort		2011 cohort	
Municipality-level rurality (ref: urban) ^a										
Sub-urban	1.02	[0.93,1.13]	1.08	[0.97,1.19]	1.08	[0.97,1.20]	1.04	[0.94,1.15]	1.01	[0.90,1.14]
Rural	1.18	[1.06,1.32]	1.24	[1.10,1.39]	1.14	[1.01,1.29]	1.16	[1.03,1.30]	1.17	[1.02,1.33]
Neighborhood-level rurality (ref: urban) ^b										
Sub-urban	0.99	[0.88,1.12]	0.90	[0.79,1.03]	1.04	[0.91,1.19]	0.97	[0.84,1.10]	0.97	[0.84,1.11]
Rural	1.07	[0.98,1.18]	1.11	[1.01,1.22]	1.16	[1.06,1.28]	1.26	[1.15,1.39]	1.20	[1.09,1.33]
Country of birth (ref: Sweden)										
European countries	1.11	[0.96,1.28]	1.03	[0.88,1.20]	1.02	[0.87,1.18]	0.97	[0.83,1.13]	0.80	[0.68,0.94]
Non-European countries	0.67	[0.50,0.90]	0.81	[0.63,1.03]	0.63	[0.49,0.80]	0.69	[0.56,0.85]	0.50	[0.41,0.62]
Age (ref: 20-29)										
30-39	1.24	[1.10,1.40]	1.29	[1.13,1.46]	1.15	[1.00,1.32]	0.84	[0.73,0.96]	0.82	[0.72,0.94]
40-49	1.51	[1.35,1.69]	1.48	[1.31,1.68]	1.62	[1.42,1.85]	1.25	[1.10,1.41]	1.07	[0.95,1.21]
50-59	1.50	[1.32,1.69]	1.65	[1.45,1.87]	1.56	[1.37,1.78]	1.41	[1.25,1.59]	1.25	[1.10,1.41]
60-69	1.34	[1.18,1.52]	1.51	[1.31,1.74]	1.63	[1.42,1.88]	1.15	[1.01,1.31]	1.06	[0.94,1.21]
≥ 70	2.16	[1.92,2.42]	2.14	[1.89,2.43]	2.06	[1.80,2.35]	1.50	[1.32,1.71]	1.42	[1.25,1.61]
Municipality-level rurality (ref: urban) x country of birth (ref: Sweden)										
Sub-urban, European countries	1.03	[0.75,1.41]	1.03	[0.74,1.42]	1.43	[1.07,1.93]	1.31	[0.97,1.78]	1.40	[1.01,1.93]
Sub-urban, non-European countries	1.02	[0.48,2.17]	0.82	[0.37,1.79]	1.20	[0.57,2.52]	1.73	[1.04,2.89]	1.07	[0.57,2.02]
Rural, European countries	1.02	[0.68,1.54]	1.32	[0.90,1.93]	1.12	[0.72,1.72]	1.11	[0.73,1.67]	1.14	[0.74,1.76]
Rural, non-European countries	2.01	[0.90,4.46]	1.23	[0.45,3.38]	2.11	[0.84,5.27]	1.18	[0.48,2.92]	0.44	[0.11,1.81]

Random-effect part of the Model

Median rate ratios between municipalities	1.11	1.14	1.15	1.11	1.17
Median rate ratios between neighborhoods	1.25	1.30	1.17	1.23	1.35

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 15. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: cross-level interaction between country of birth and neighborhood-level rurality on suicide.

	1991 cohort		1996 cohort		2001 cohort		2006 cohort		2011 cohort	
Municipality-level rurality (ref: urban) ^a										
Sub-urban	1.03	[0.93,1.13]	1.08	[0.97,1.19]	1.11	[1.00,1.23]	1.08	[0.97,1.19]	1.04	[0.93,1.16]
Rural	1.19	[1.07,1.33]	1.26	[1.12,1.41]	1.16	[1.03,1.31]	1.18	[1.05,1.32]	1.17	[1.03,1.33]
Neighborhood-level rurality (ref: urban) ^b										
Sub-urban	1.01	[0.89,1.15]	0.88	[0.77,1.02]	1.04	[0.91,1.19]	0.96	[0.84,1.11]	0.91	[0.79,1.05]
Rural	1.06	[0.96,1.16]	1.11	[1.01,1.22]	1.13	[1.03,1.25]	1.25	[1.13,1.37]	1.18	[1.07,1.31]
Country of birth (ref: Sweden)										
European countries	1.10	[0.96,1.26]	1.04	[0.91,1.20]	1.05	[0.91,1.22]	1.03	[0.90,1.19]	0.80	[0.68,0.93]
Non-European countries	0.70	[0.54,0.92]	0.81	[0.64,1.02]	0.64	[0.51,0.81]	0.73	[0.60,0.88]	0.47	[0.38,0.58]
Age (ref: 20-29)										
30-39	1.24	[1.10,1.40]	1.28	[1.13,1.46]	1.15	[1.00,1.32]	0.84	[0.73,0.96]	0.82	[0.72,0.94]
40-49	1.51	[1.35,1.69]	1.48	[1.31,1.68]	1.62	[1.42,1.85]	1.25	[1.10,1.41]	1.07	[0.95,1.21]
50-59	1.49	[1.32,1.69]	1.65	[1.45,1.87]	1.56	[1.37,1.78]	1.41	[1.25,1.59]	1.25	[1.10,1.41]
60-69	1.34	[1.17,1.52]	1.51	[1.31,1.74]	1.63	[1.42,1.88]	1.15	[1.01,1.31]	1.06	[0.94,1.21]
≥ 70	2.16	[1.92,2.42]	2.14	[1.88,2.43]	2.06	[1.80,2.35]	1.50	[1.31,1.70]	1.42	[1.26,1.61]
Neighborhood-level rurality (ref: urban) x country of birth (ref: Sweden)										
Sub-urban, European countries	0.72	[0.42,1.23]	1.42	[0.90,2.23]	1.04	[0.64,1.69]	1.03	[0.62,1.69]	1.88	[1.21,2.90]
Sub-urban, non-European countries	0.97	[0.23,3.98]	0.57	[0.08,4.14]	0.53	[0.07,3.80]	1.00	[0.32,3.18]	1.85	[0.74,4.59]
Rural, European countries	1.33	[0.94,1.87]	0.95	[0.63,1.42]	1.39	[0.99,1.96]	1.02	[0.71,1.45]	1.21	[0.84,1.75]
Rural, non-European countries	1.44	[0.45,4.62]	0.97	[0.24,3.95]	2.60	[1.04,6.46]	2.08	[0.96,4.50]	1.81	[0.73,4.46]

Random-effect part of the Model

Median rate ratios between municipalities	1.11	1.14	1.15	1.11	1.17
Median rate ratios between neighborhoods	1.25	1.30	1.17	1.23	1.36

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 16. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of women: cross-level interaction between country of birth and municipality-level rurality on suicide.

	1991 cohort		1996 cohort		2001 cohort		2006 cohort		2011 cohort	
Municipality-level rurality (ref: urban) ^a										
Sub-urban	0.86	[0.73,1.02]	0.82	[0.69,0.97]	0.88	[0.74,1.03]	1.05	[0.88,1.24]	0.93	[0.78,1.10]
Rural	0.93	[0.77,1.13]	0.83	[0.67,1.02]	0.72	[0.58,0.89]	0.96	[0.78,1.19]	0.97	[0.79,1.19]
Neighborhood-level rurality (ref: urban) ^b										
Sub-urban	0.80	[0.66,0.98]	0.82	[0.66,1.02]	0.71	[0.56,0.89]	0.89	[0.72,1.11]	0.71	[0.57,0.90]
Rural	0.73	[0.62,0.86]	0.59	[0.49,0.72]	0.75	[0.62,0.89]	0.75	[0.63,0.90]	0.88	[0.74,1.04]
Country of birth (ref: Sweden)										
European countries	1.13	[0.94,1.37]	1.41	[1.18,1.69]	1.17	[0.96,1.43]	1.20	[0.98,1.47]	1.04	[0.85,1.27]
Non-European countries	0.64	[0.40,1.02]	0.75	[0.51,1.10]	0.88	[0.64,1.21]	0.59	[0.42,0.83]	0.59	[0.45,0.79]
Age (ref: 20-29)										
30-39	1.48	[1.21,1.80]	1.31	[1.06,1.62]	1.10	[0.88,1.36]	1.15	[0.92,1.44]	0.94	[0.76,1.16]
40-49	1.96	[1.63,2.36]	1.74	[1.42,2.13]	1.38	[1.12,1.70]	1.56	[1.26,1.93]	1.44	[1.20,1.74]
50-59	1.98	[1.63,2.41]	1.85	[1.51,2.27]	1.62	[1.33,1.97]	1.55	[1.25,1.92]	1.45	[1.19,1.75]
60-69	1.82	[1.49,2.23]	1.51	[1.21,1.89]	1.50	[1.20,1.86]	1.43	[1.15,1.79]	1.20	[0.98,1.46]
≥ 70	2.05	[1.70,2.46]	1.65	[1.35,2.02]	1.41	[1.15,1.73]	1.16	[0.93,1.45]	1.13	[0.93,1.38]
Municipality-level rurality (ref: urban) x country of birth (ref: Sweden)										
Sub-urban, European countries	1.38	[0.91,2.11]	1.39	[0.92,2.09]	1.32	[0.84,2.06]	0.72	[0.42,1.22]	1.05	[0.65,1.70]
Sub-urban, non-European countries	1.35	[0.40,4.63]	0.00	-	1.37	[0.53,3.51]	0.00	-	1.53	[0.74,3.16]
Rural, European countries	1.17	[0.65,2.08]	0.84	[0.43,1.65]	1.77	[1.00,3.15]	0.74	[0.35,1.56]	1.25	[0.70,2.26]
Rural, non-European countries	1.22	[0.16,9.17]	0.00	-	0.96	[0.13,7.08]	0.70	[0.10,5.19]	1.51	[0.54,4.24]

Random-effect part of the Model

Median rate ratios between municipalities	1.25	1.14	1.12	1.18	1.18
Median rate ratios between neighborhoods	1.24	1.39	1.00	1.00	1.41

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 17. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of women: cross-level interaction between country of birth and neighborhood-level rurality on suicide.

	1991 cohort		1996 cohort		2001 cohort		2006 cohort		2011 cohort	
Municipality-level rurality (ref: urban) ^a										
Sub-urban	0.89	[0.76,1.05]	0.84	[0.71,0.98]	0.91	[0.78,1.06]	1.00	[0.85,1.17]	0.94	[0.80,1.11]
Rural	0.95	[0.79,1.14]	0.81	[0.66,0.99]	0.76	[0.62,0.94]	0.93	[0.76,1.15]	1.00	[0.83,1.22]
Neighborhood-level rurality (ref: urban) ^b										
Sub-urban	0.81	[0.66,1.00]	0.79	[0.63,0.99]	0.69	[0.54,0.89]	0.81	[0.64,1.03]	0.70	[0.55,0.90]
Rural	0.71	[0.59,0.84]	0.60	[0.49,0.74]	0.73	[0.60,0.88]	0.76	[0.63,0.92]	0.86	[0.72,1.03]
Country of birth (ref: Sweden)										
European countries	1.19	[1.00,1.41]	1.45	[1.22,1.71]	1.24	[1.04,1.49]	1.04	[0.85,1.27]	1.06	[0.88,1.27]
Non-European countries	0.64	[0.41,1.00]	0.66	[0.45,0.98]	0.91	[0.67,1.23]	0.54	[0.39,0.77]	0.61	[0.47,0.80]
Age (ref: 20-29)										
30-39	1.48	[1.21,1.80]	1.31	[1.06,1.62]	1.10	[0.88,1.36]	1.15	[0.92,1.44]	0.94	[0.76,1.16]
40-49	1.96	[1.63,2.36]	1.74	[1.43,2.13]	1.38	[1.12,1.70]	1.56	[1.27,1.93]	1.44	[1.20,1.74]
50-59	1.98	[1.63,2.41]	1.85	[1.51,2.27]	1.62	[1.32,1.97]	1.56	[1.26,1.93]	1.44	[1.19,1.75]
60-69	1.82	[1.49,2.23]	1.51	[1.21,1.89]	1.49	[1.20,1.86]	1.44	[1.15,1.79]	1.19	[0.98,1.46]
≥ 70	2.04	[1.70,2.46]	1.65	[1.35,2.02]	1.41	[1.15,1.73]	1.17	[0.93,1.46]	1.13	[0.92,1.37]
Neighborhood-level rurality (ref: urban) x country of birth (ref: Sweden)										
Sub-urban, European countries	0.91	[0.43,1.91]	1.52	[0.84,2.75]	1.20	[0.56,2.54]	2.42	[1.36,4.29]	0.77	[0.31,1.95]
Sub-urban, non-European countries	0.00	-	0.00	-	1.12	[0.15,8.22]	0.00	-	2.61	[0.92,7.39]
Rural, European countries	1.31	[0.75,2.27]	0.80	[0.38,1.67]	1.34	[0.75,2.39]	0.92	[0.46,1.86]	1.23	[0.71,2.12]
Rural, non-European countries	3.98	[0.92,17.19]	2.28	[0.31,16.94]	1.04	[0.14,7.60]	0.00	-	0.97	[0.23,4.01]

Random-effect part of the Model

Median rate ratios between municipalities	1.25	1.14	1.11	1.19	1.18
Median rate ratios between neighborhoods	1.25	1.39	1.00	1.00	1.41

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Supplementary Table 18. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] by gender: the results of multilevel Poisson regression analyses in all cohorts.

	1991 cohort		1996 cohort		2001 cohort		2006 cohort		2011 cohort	
Men										
Municipality-level rurality^a										
Urban	Ref.		Ref.		Ref.		Ref.		Ref.	
Sub-urban	1.03	[0.93,1.13]	1.08	[0.97,1.19]	1.11	[1.00,1.24]	1.08	[0.98,1.19]	1.04	[0.93,1.16]
Rural	1.19	[1.07,1.33]	1.26	[1.12,1.41]	1.16	[1.03,1.31]	1.18	[1.05,1.32]	1.17	[1.03,1.33]
Neighborhood-level rurality^b										
Urban	Ref.		Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.99	[0.88,1.12]	0.90	[0.79,1.03]	1.04	[0.91,1.19]	0.97	[0.85,1.10]	0.97	[0.84,1.11]
Rural	1.07	[0.98,1.17]	1.11	[1.01,1.22]	1.16	[1.06,1.28]	1.26	[1.14,1.38]	1.20	[1.09,1.33]
Women										
Municipality-level rurality^a										
Urban	Ref.		Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.89	[0.76,1.05]	0.84	[0.72,0.98]	0.91	[0.78,1.06]	1.00	[0.85,1.18]	0.95	[0.80,1.11]
Rural	0.95	[0.79,1.14]	0.81	[0.66,0.99]	0.76	[0.62,0.94]	0.93	[0.76,1.15]	1.01	[0.83,1.22]
Neighborhood-level rurality^b										
Urban	Ref.		Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.81	[0.66,0.98]	0.83	[0.67,1.02]	0.71	[0.56,0.89]	0.89	[0.72,1.11]	0.71	[0.57,0.90]
Rural	0.73	[0.62,0.86]	0.59	[0.49,0.72]	0.74	[0.62,0.89]	0.75	[0.63,0.91]	0.88	[0.74,1.04]

^a We used population density as a measure of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Covariates: age and country of birth

Supplementary Table 19. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 1991-1995 Swedish registry-based cohort data.

	Model 1		Model 2		Model 3		Model 4	
Municipality-level rurality^a								
Urban	Ref.				Ref.		Ref.	
Sub-urban	1.03	[0.93,1.13]	1.07	[0.97,1.18]	1.00	[0.92,1.10]	1.02	[0.93,1.12]
Rural	1.19	[1.07,1.33]	1.25	[1.12,1.39]	1.12	[1.01,1.25]	1.18	[1.06,1.31]
<i>% change from Model 1 in excess rate from urban</i>			31.6%		-36.8%		-5.3%	
Neighborhood-level rurality^b								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.99	[0.88,1.12]	1.03	[0.91,1.16]	1.04	[0.92,1.18]	0.98	[0.87,1.11]
Rural	1.07	[0.98,1.17]	1.13	[1.03,1.23]	1.10	[1.01,1.21]	1.01	[0.90,1.13]
<i>% change from Model 1 in excess rate from urban</i>			85.7%		42.9%		-85.7%	
Proportion of foreign-born people per neighborhood population (/person)			3.17 [1.97,5.11]					
Proportion of unemployed per neighborhood population (/person)					3.81 [2.62,5.54]			
Proportion of people with the lowest income quintile per neighborhood population (/person)							2.87 [0.85,9.71]	
<i>Random-effect part of the model</i>								
Median rate ratios between municipalities								
Null=1.15	1.11		1.13		1.08		1.11	
Median rate ratios between neighborhoods								
Null=1.24	1.25		1.23		1.23		1.25	

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Model 1: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 2: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of foreign-born people per the neighborhood population

Model 3: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of unemployed per the neighborhood population

Model 4: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of people with the lowest income quintile per the neighborhood population

Supplementary Table 20. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 1996-2000 Swedish registry-based cohort data.

	Model 1		Model 2		Model 3		Model 4		
Municipality-level rurality^a									
Urban	Ref.				Ref.		Ref.		
Sub-urban	1.08	[0.97,1.19]	1.13	[1.02,1.25]	1.03	[0.93,1.14]	1.07	[0.97,1.19]	
Rural	1.26	[1.12,1.41]	1.33	[1.19,1.50]	1.13	[1.00,1.26]	1.25	[1.12,1.41]	
<i>% change from Model 1 in excess rate from urban</i>			26.9%		-50.0%		-3.8%		
Neighborhood-level rurality^b									
Urban	Ref.		Ref.		Ref.		Ref.		
Sub-urban	0.90	[0.79,1.03]	0.96	[0.84,1.10]	1.00	[0.88,1.15]	0.89	[0.78,1.02]	
Rural	1.11	[1.01,1.22]	1.2	[1.09,1.33]	1.20	[1.09,1.33]	0.97	[0.87,1.08]	
<i>% change from Model 1 in excess rate from urban</i>			81.8%		81.8%		-127.3%		
Proportion of foreign-born people per neighborhood population (/person)			4.53 [2.99,6.88]						
Proportion of unemployed per neighborhood population (/person)					8.95 [6.10,13.13]				
Proportion of people with the lowest income quintile per neighborhood population (/person)							16.87 [5.68,50.07]		
<i>Random-effect part of the model</i>									
Median rate ratios between municipalities									
Null=1.21	1.14		1.14		1.13		1.13		
Median rate ratios between neighborhoods									
Null=1.29	1.30		1.26		1.21		1.29		

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Model 1: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 2: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of foreign-born people per the neighborhood population

Model 3: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of unemployed per the neighborhood population

Model 4: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of people with the lowest income quintile per the neighborhood population

Supplementary Table 21. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 2001-2005 Swedish registry-based cohort data.

	Model 1		Model 2		Model 3		Model 4	
Municipality-level rurality^a								
Urban	Ref.				Ref.		Ref.	
Sub-urban	1.11	[1.00,1.24]	1.17	[1.05,1.29]	1.05	[0.95,1.16]	1.10	[0.99,1.22]
Rural	1.16	[1.03,1.31]	1.22	[1.08,1.38]	1.01	[0.90,1.14]	1.11	[0.99,1.25]
<i>% change from Model 1 in excess rate from urban</i>			37.5%		-93.8%		-31.2%	
Neighborhood-level rurality^b								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	1.04	[0.91,1.19]	1.11	[0.97,1.26]	1.13	[0.99,1.28]	1.05	[0.92,1.19]
Rural	1.16	[1.06,1.28]	1.25	[1.13,1.38]	1.25	[1.13,1.38]	1.05	[0.94,1.16]
<i>% change from Model 1 in excess rate from urban</i>			56.3%		56.3%		-68.8%	
Proportion of foreign-born people per neighborhood population (/person)			3.93 [2.63,5.87]					
Proportion of unemployed per neighborhood population (/person)					7.88 [5.18,11.99]			
Proportion of people with the lowest income quintile per neighborhood population (/person)							17.55 [7.10,43.39]	
<i>Random-effect part of the model</i>								
Median rate ratios between municipalities								
Null=1.18	1.15		1.14		1.13		1.13	
Median rate ratios between neighborhoods								
Null=1.18	1.17		1.13		1.07		1.15	

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Model 1: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 2: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of foreign-born people per the neighborhood population

Model 3: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of unemployed per the neighborhood population

Model 4: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of people with the lowest income quintile per the neighborhood population

Supplementary Table 22. Suicide Incidence Rate Ratios (IRR) [95% Confidence Intervals] of men: the results of multilevel Poisson regression analyses using 2006-2011 Swedish registry-based cohort data.

	Model 1		Model 2		Model 3		Model 4	
Municipality-level rurality^a								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	1.08	[0.98,1.19]	1.12	[1.02,1.24]	1.01	[0.92,1.11]	1.08	[0.98,1.18]
Rural	1.18	[1.05,1.32]	1.23	[1.10,1.38]	1.04	[0.93,1.16]	1.16	[1.04,1.30]
<i>% change from Model 1 in excess rate from urban</i>			27.8%		-77.8%		-11.1%	
Neighborhood-level rurality^b								
Urban	Ref.		Ref.		Ref.		Ref.	
Sub-urban	0.97	[0.85,1.10]	1.02	[0.90,1.17]	1.04	[0.91,1.18]	0.98	[0.86,1.12]
Rural	1.26	[1.14,1.38]	1.35	[1.22,1.48]	1.38	[1.25,1.52]	1.19	[1.08,1.31]
<i>% change from Model 1 in excess rate from urban</i>			34.6%		46.2%		-26.9%	
Proportion of foreign-born people per neighborhood population (/person)			3.12 [2.13,4.56]					
Proportion of unemployed per neighborhood population (/person)					8.81 [5.73,13.54]			
Proportion of people with the lowest income quintile per neighborhood population (/person)							9.35 [4.14,21.14]	
<i>Random-effect part of the model</i>								
Median rate ratios between municipalities								
Null=1.16	1.11		1.10		1.06		1.08	
Median rate ratios between neighborhoods								
Null=1.26	1.23		1.21		1.17		1.22	

^a Population density was used as an indicator of municipality-level rurality.

^b For neighborhood-level rurality we used DeSO units, which are demographic statistical areas created by the Swedish government.

Model 1: age, country of birth, municipality-level rurality, neighborhood-level rurality

Model 2: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of foreign-born people per the neighborhood population

Model 3: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of unemployed per the neighborhood population

Model 4: age, country of birth, municipality-level rurality, neighborhood-level rurality, proportion of people with the lowest income quintile per the neighborhood population

Supplementary Table 23. Number of men and women by country of birth, municipality-level rurality and neighborhood-level rurality.

Rurality	Country of birth	1991 cohort	1996 cohort	2001 cohort	2006 cohort	2011 cohort
Men						
Urban municipalities	Sweden	1,622,706	1,704,371	1,766,466	1,801,466	1,882,165
	European countries	180,824	196,194	206,129	220,195	252,135
	Non-European countries	72,029	100,638	130,317	172,056	237,373
Rural municipalities	Sweden	450,454	443,400	426,466	419,003	415,387
	European countries	19,275	20,925	21,090	23,860	26,589
	Non-European countries	4,712	4,125	4,346	6,620	9,993
Women						
Urban municipalities	Sweden	1,750,450	1,824,791	1,870,779	1,885,955	1,947,437
	European countries	208,731	231,238	242,833	257,812	283,465
	Non-European countries	59,780	91,767	126,333	168,272	233,799
Rural municipalities	Sweden	442,073	436,538	420,172	408,991	401,710
	European countries	26,372	28,497	27,944	29,823	31,386
	Non-European countries	3,771	4,231	5,077	8,291	13,040
Men						
Urban neighborhoods	Sweden	1,952,127	1,998,586	2,022,204	2,046,155	2,120,882
	European countries	202,119	221,352	228,807	244,115	275,669
	Non-European countries	83,414	111,546	140,823	187,126	259,579
Rural neighborhoods	Sweden	588,612	590,016	583,056	583,831	586,458
	European countries	23,924	24,680	26,851	30,990	36,584
	Non-European countries	2,704	2,536	3,136	4,453	6,123

Women

Urban neighborhoods	Sweden	2,137,022	2,174,390	2,177,351	2,177,645	2,229,203
	European countries	235,677	263,368	272,612	289,152	314,760
	Non-European countries	68,393	101,746	136,609	183,437	257,006
Rural neighborhoods	Sweden	531,569	534,745	528,674	527,421	527,190
	European countries	29,119	30,077	31,383	34,205	37,748
	Non-European countries	2,782	3,296	4,484	7,175	10,536

Supplementary Table 24. Health equity policies and suicide prevention programs in Sweden between 1991 and 2015.

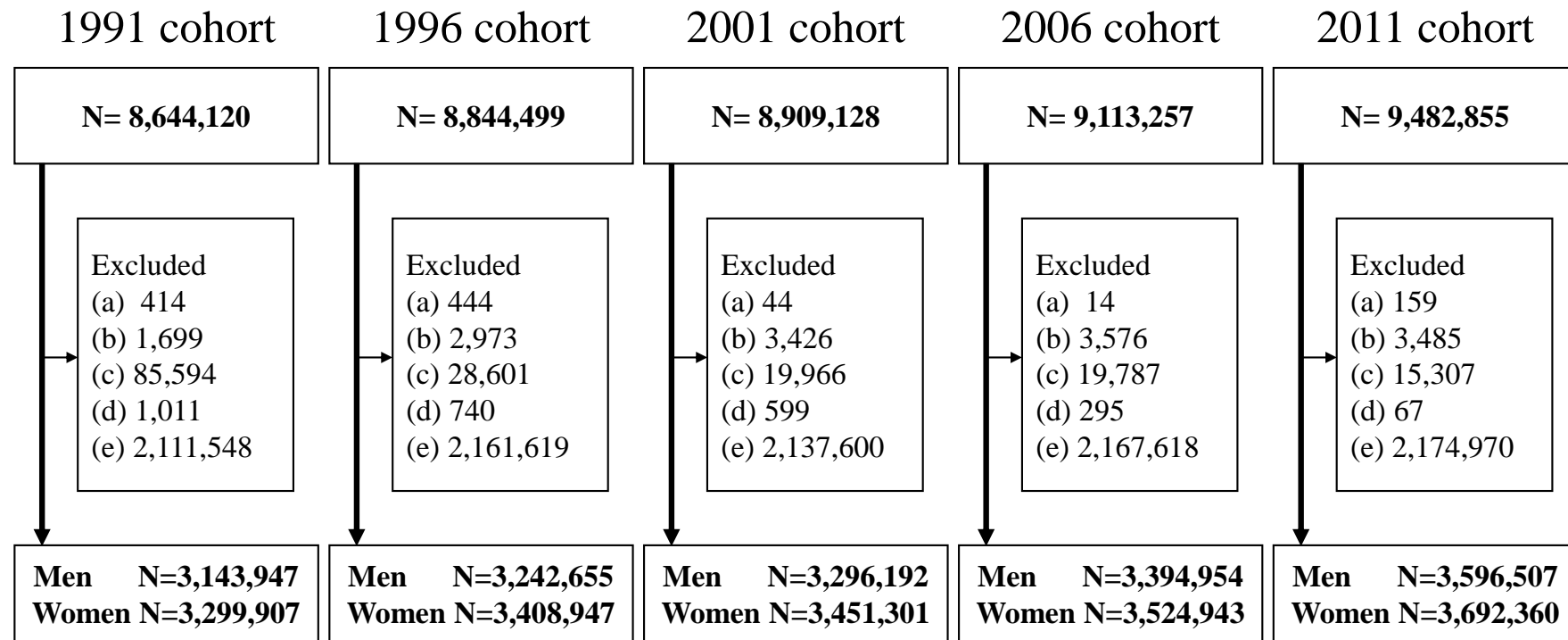
	Period				
	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015
Health equity policies	1991: A public health bill proposed increased health equity as an overarching objective in public health policies. ^{a)}	The second half of the 1990s: A public health policy framework based on a SDH* approach was proposed. ^{a)}	2003: A revised version of the framework was presented and adopted by Parliament. ^{a)}	2008: The World Health Organization's Commission on SDH* presented its recommendations. ^{b)}	The 2010s: Various local and regional commissions were launched. 2014: The Prime Minister stated that avoidable health inequalities should be eliminated within a generation. 2015: A national Commission for Equity in Health was set up. ^{a)}
Suicide prevention programs	1995: The Swedish National Program to Develop Suicide Prevention was established. The program focused on the following ten strategic areas: 1) Increased awareness; 2) Support and treatment; 3) Children and young people; 4) Adults; 5) The elderly; 6) Vulnerable groups; 7) Training and development; 8) Reduced availability of instruments of suicide; 9) National expertise in suicidology; 10) Regulatory systems. ^{c)}			2008: The National Action Program for Suicide Prevention was ratified by Parliament. The program included the following nine strategic areas of action: 1) Promote good life opportunities for less privileged groups; 2) Reduce alcohol consumption in the population and in groups at high risk for suicide; 3) Reduce access to means and methods of suicide; 4) View suicide as a psychological mistake; 5) Improve medical, psychological and psychosocial initiatives; 6) Distribute knowledge about evidence-based methods for reducing suicide; 7) Raise skill levels among staff and other key individuals in the care services; 8) Perform "root cause" or event analyses after suicide; 9) Support voluntary organizations. ^{d,e)}	

*Social Determinants of Health.

Source:

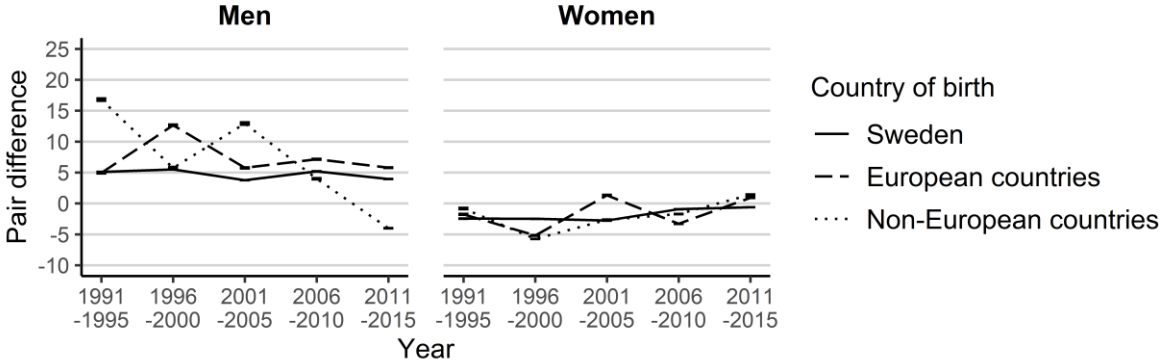
- a) Lundberg O. The next step towards more equity in health in Sweden: how can we close the gap in a generation? Scand J Public Health. 2018;46: 19–27. doi:10.1177/1403494818765702
- b) Commission on Social Determinants of Health. Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission on Social Determinants of Health. 2008. [cited 28 Dec 2021]. Available: <https://www.who.int/publications/i/item/9789241563703>
- c) The Swedish National Council for Suicide Prevention. Support in suicidal crises: the Swedish National Program to develop suicide prevention. Crisis. 1997;18: 65-72. doi:10.1027/0227-5910.18.2.65
- d) Public Health Agency of Sweden. National action program for suicide prevention. 2016. [cited 28 Dec 2021]. Available: <https://www.folkhalsomyndigheten.se/publicerat-material/publikationsarkiv/n/national-action-programme-for-suicide-prevention/>
- e) World Health Organization. National suicide prevention strategies: progress, examples and indicators. World Health Organization. 2018. [cited 28 Dec 2021]. Available: <https://apps.who.int/iris/bitstream/handle/10665/279765/9789241515016-eng.pdf?ua=1>

Supplementary Figure 8. Flow chart of the study population. We excluded the data of individuals (a) that were duplicated, (b) who were missing an individual ID number, and (c) who were missing residential information. To estimate area-level socioeconomic status, we also excluded (d) people who lived in very small neighborhoods (50 residents or fewer). In addition, we also excluded the data of individuals (e) under 20 years old at baseline.

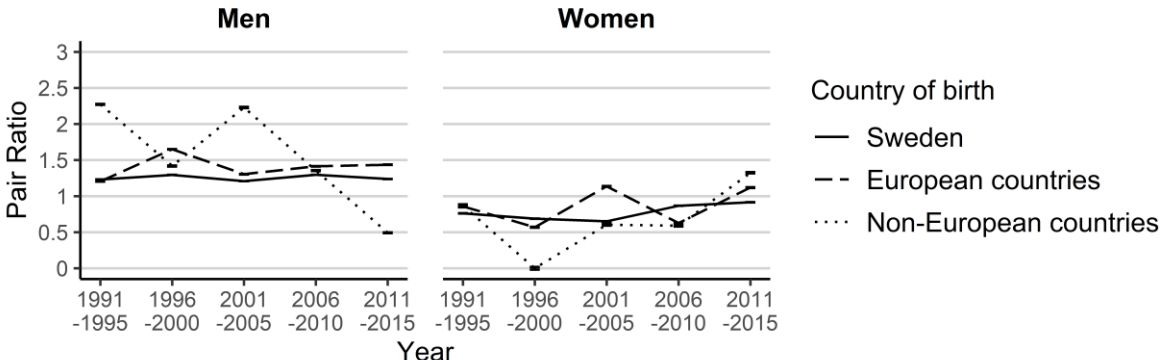


Supplementary Figure 9. Secular trends in health inequality measures of suicide incidence per 100,000 person-years with 95% confidence intervals between urban and rural municipalities by country of birth and gender. A shows the Pair difference and B the Pair Ratio.

A. Pair Difference (ref. urban municipality)

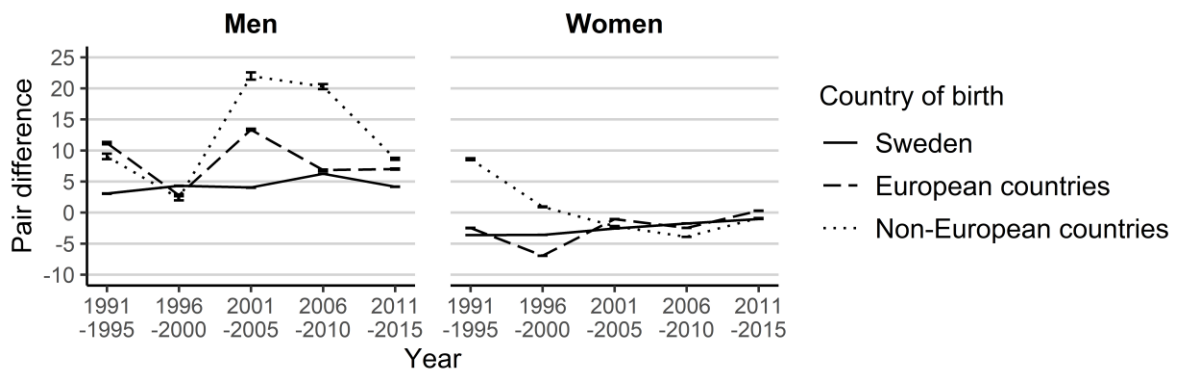


B. Pair Ratio (ref. urban municipality)

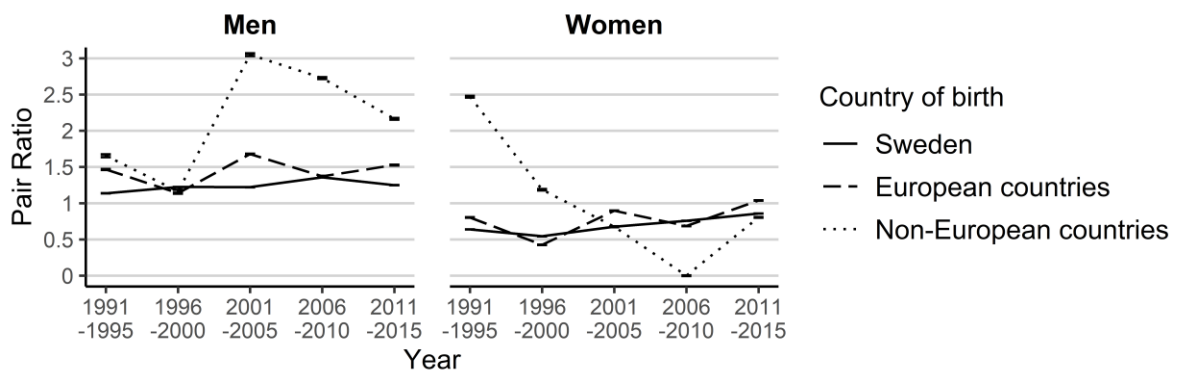


Supplementary Figure 10. Secular trends in health inequality measures of suicide incidence per 100,000 person-years with 95% confidence intervals between urban and rural neighborhoods by country of birth and gender. A shows the Pair difference and B the Pair Ratio.

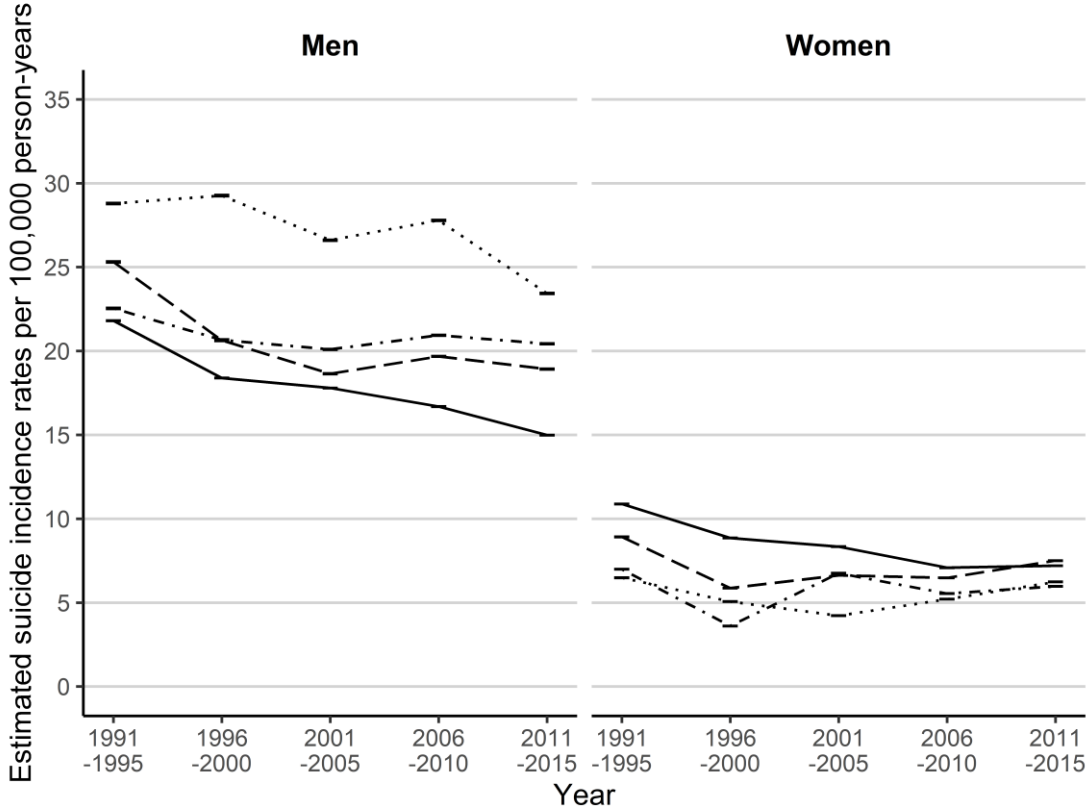
A. Pair Difference (ref. urban neighborhood)



B. Pair Ratio (ref. urban neighborhood)



Supplementary Figure 11. Secular trends in estimated suicide incidence per 100,000 person-years with 95% confidence intervals by gender: cross-level interaction between municipality-level rurality and neighborhood-level rurality on suicide. The estimates were derived from three-level multilevel Poisson analyses adjusted for age, country of birth, municipality-level rurality, and neighborhood-level rurality.



- Rurality
- Urban neighborhoods in urban municipalities
 - Urban neighborhoods in rural municipalities
 - Rural neighborhoods in urban municipalities
 - Rural neighborhoods in rural municipalities