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# One stream, two channels? A parallel-process latent class growth model of homicide rates and suicide rates in 183 countries, between 2000 and 2019

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ABSTRACT

*Background:* Suicide and homicide have long been viewed in Western culture as moral, ethical and legal equivalents. This view has underpinned many theoretical and empirical explorations into their relationship over the centuries. However, there has been little evaluation of longitudinal heterogeneity.

*Methods:* Suicide and homicide rates in 183 countries between 2000 and 2019 were collected from the World Health Organization Global Health Observatory Repository. Corresponding structural variables (i.e., GDP per capita, unemployment rate, percentage of urban population, percentage of elderly population, and Gini index) were acquired from The World Bank and Standardized World Income Inequality Database. Parallel-process latent class growth modelling was applied to identify different classes within the joint suicide and homicide rate trajectories. Multinomial logistic regression examined relationships between the structural covariates and trajectory classes.

*Results:* Four trajectory classes were identified, two with inverse relationships between suicide and homicide, and two with parallel relationships: 1) countries with increasing suicide rates and decreasing homicide rates ("suicide up, homicide down": UD, $n = 41$) or 2) countries with decreasing suicide rates and increasing homicide rates ("suicide down, homicide up": DU, $n = 17$); and 3) countries where suicide and homicide rates both trended up (UU, $n = 19$), or 4) both trended down (DD, $n = 106$). A higher average annual growth rate (AAGR) of GDP per capita was related to an increased possibility of being in DD than in DU. Countries with higher AAGR in unemployment rates were more likely to be in UD and UU than in DD, while those with higher AAGR in urbanization were less likely to be in UD than in DD.

*Conclusion:* The over-time relationship between suicide and homicide is heterogenous and complex. It is influenced differently by GDP per capita, urbanization and unemployment in different countries, and it is not well described by a single theory.

## 1. Introduction

### 1.1. Integrating suicide and homicide into one framework

It is estimated that, every year, more than 700,000 people die by suicide (World Health Organization, 2021), and more than 400,000 deaths globally are attributed to homicide (United Nations Office on Drugs and Crime, 2022). Although suicide and homicide are often studied separately, both phenomena are historically perceived in Western culture as morally, ethically, and legally equivalent (see Whitt, 1994a for review). Suicide can be viewed as a self-murder process, and the only difference between suicide and homicide is that the victim of suicide is also the perpetrator. Interpretation of these two phenomena under one framework has been of long-standing interest in sociology and psychology research.

In the early nineteenth century, Morselli (1879) and Ferri (1883–84) analyzed time-series data and plotted ecological maps of suicide rates and homicide rates across Europe, discovering an inverse relationship between these two types of violence. These authors claimed that suicide and homicide were unique manifestations stemming from parallel

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forces. Similarly, Henry and Short (1954) adopted a frustration-aggression perspective and proposed that suicide (a form of self-directed aggression) and homicide (a form of other-directed aggression) were related, where both were alternative responses to frustration. Their studies showed that suicide rates were positively related to the business cycle, while homicide rates were negatively related. However, other studies suggested a positive and parallel rate relationship between suicide and homicide (Holinger & Klemen, 1982; Machado et al., 2020; McKenna et al., 1997). Although these inconsistencies are, in part, explained by different sampling approaches, sample sizes and analytic strategies, there are also suggestions that the rate relationship between suicide and homicide varies across countries, and time periods (e.g., Bills & Li, 2005; Fountoulakis & Gonda, 2017).

Another stream of research in this area has used lethal violence rate (LVR) and suicide-homicide ratio (SHR) to explore the relationship between suicide and homicide. These two measures were firstly introduced by Whitt (1994b), who also proposed an integrated model. The model incorporated the attribution theory, describing suicide and homicide as two distinct channels in a single stream of lethal violence. When the causes of frustration are attributed inwardly, self-directed violence is more likely to occur. Conversely, external attribution of frustrations increases the risk of homicide, an 'other-directed violence'. Research undertaken within this framework has explored how structural factors influence the amount of violence (LVR, calculated by the sum of suicide rates and homicide rates) and the direction of the expression of violence (SHR, calculated by dividing the suicide rates by LVR). Social welfare expenditure and urbanization were proposed as significant factors influencing LVR; income inequality and ethnic/linguistic fractionalization decreased SHR, while economic growth was positively associated with SHR (Chon, 2013; He et al., 2003; Tuttle, 2018). However, SHR is not a direct indicator of the relationship between suicide and homicide. For example, increased SHR can be found in several scenarios: 1) suicide rates increase while homicide rates remain unchanged; 2) homicide rates decrease while suicide rates are unchanged; 3) both suicide rates and homicide rates increase, but suicide rates increase faster.

### 1.2. Using parallel-process trajectory models to study the relationship between suicide and homicide

There have been ongoing attempts to understand suicide and homicide under one unifying framework, using both theoretical and empirical research. However, there have been limitations in the design and interpretation of these studies. The first approach that examined the relationship between the two types of violence directly seldom incorporated covariates in the analysis, and failed to capture the dynamics in the relationship due to methodological restrictions. The second approach using LVR and SHR explored the influencing factors for the volume and the direction of violence, but the synthesized indicators obscured the true relationship between suicide and homicide.

Parallel-process GMM and parallel-process LCGM (also referred to as dual trajectory model/joint trajectory model in some literature) can be used to explore the heterogeneity in the joint trajectories of two variables, which are extensions of univariate growth mixture modeling (GMM) and latent class growth modeling (LCGM). These modelling techniques may provide new insights into the relationship between suicide and homicide. GMM and LCGM are finite mixture models estimated by maximum likelihood, capable of classifying the subjects into distinct classes based on the longitudinal changes of the indicator (Jung & Wickrama, 2008). The trajectory of each class has its own growth factors (i.e., intercept, slope, and higher order terms), and the probability of belonging to each class is estimated for each subject (Muthén, 2004). LCGM can be seen as a specific form of GMM. The latter allows for within-class variance, whereas the former assumes homogeneity across subjects within classes, requiring far fewer parameters to be estimated. Therefore, LCGM is preferable when the sample size is small, or nonconvergence issues arise in complex model settings (Berlin et al., 2014). Previous studies have employed LCGM to explore the heterogeneity in homicide trends on country-level (Tuttle et al., 2018), and city level (Cho et al., 2021; McCall et al., 2011; Peres & Nivette, 2017).

To build joint trajectory models, there have been two approaches. The first one examined the trajectories of the two indicators in two separate GMMs/LCGMs, and then correlated the two trajectory class variables. In the second one, the trajectories of the two indicators share one trajectory class variable. Although informative, the first approach may be inadequate when managing the appropriate number of classes and the meaningfulness of the subgroups (Zhou et al., 2022). For example, if each of the two indicators has three classes, their combination will generate nine classes, among which some may account for only a small proportion of the total sample. Thus, the second approach works better for smaller samples.

### 1.3. Aims of this study

Despite decades of research, the relationship between suicide and homicide has not been thoroughly investigated. To our knowledge, no study has examined heterogeneity in the suicide-homicide relationship from a longitudinal perspective. By applying growth mixture modeling and multinomial logistic regression, this study aimed to 1) examine the heterogeneity of longitudinal trajectories of suicide rates and homicide rates around the world, and 2) explore the factors that contribute to the heterogeneity.

## 2. Methods

### 2.1. Data

Data came from three sources: 1) Crude suicide rates and homicide rates per 100,000 population from 2000 to 2019, were collected from the WHO Global Health Observatory (World Health Organization, 2022), for 183 countries; 2) Yearly statistics of GDP per capita, unemployment rate, urban population (% of total population), and population aged 65 years and above (% of total population) from 2000 to 2019 for each country, were acquired from The World Bank (World Bank, 2022); 3) The Gini index (a summary measure of income inequality) was obtained from Standardized World Income Inequality Database (SWIID) (Solt, 2020). SWIID was established for cross-national comparable studies, providing both gross and net income inequality indices of 196 countries, for as many years as possible from 1960 to the present. We adopted the net Gini index as per previous studies (Altheimer & Boswell, 2012; Chon, 2016). The indices range from 0 to 100, with higher values indicating more unequal income distribution.

### 2.2. Analytic strategy

Two steps were taken when investigating the suicide-homicide relationships in the 183-country dataset. In the first step, the heterogeneity of trajectories was explored, using a parallel-process latent class growth model. To reduce the complexity of the model and to balance the influence of potential outliers, the suicide rates and homicide rates for each country were averaged in three-year blocks across the 20 years of data (giving seven data points). Note that the last data point was the average of the 2018 and 2019 rates only. The classification in growth mixture modeling is largely determined by the intercepts when the levels of the indicator vary strongly, which means heterogeneity in trend will be hard to capture (Heggeseth & Jewell, 2018). To tackle this problem, it has been suggested that the indicators should be standardized within each analysis unit (Magrini, 2022). Thus, we further standardized the seven averaged time points of suicide rates and homicide rates within each country. Considering the small sample size ($n = 183$ countries), the trajectories of suicide rates and homicide rates shared one trajectory class variable in our model. Both linear growth models and quadratic growth models were fitted, to account for possible

non-linear trajectories. To identify the best classification solution, the number of classes was gradually increased from two to six, and each model was assessed by five indicators: 1) Bayesian Information Criterion (BIC); 2) Entropy; 3) Lo-Mendell-Rubin likelihood ratio test (LMR-LRT); 4) the size of each class; and 5) the interpretability and the parsimony of the model. A smaller BIC indicates better model fit; a higher entropy indicates a higher accuracy of classification (Asparouhov & Muthén, 2014; Nagin & Tremblay, 2001; Nylund et al., 2007). A significant LMR-LRT *p-value* means that a model with k classes fits better than the model with k-l classes (Asparouhov & Muthén, 2014; Nagin & Tremblay, 2001). The smallest class should comprise at least five percent of the total sample (Nylund et al., 2007).

In the second step, multinomial logistic regression was applied to determine how baseline status (covariate levels in 2000) and variations of structural covariates related to the classes generated in step one. The overall variation of each covariate was defined by the average of its annual growth rates (AAGR). This calculation was based on the available data (details about missing values are reported in the Appendix).

The parallel-process LCGM was performed in Mplus 8.7. Descriptive analysis and multinomial logistic regression were conducted in SPSS 27.0.

## 3. Results

### 3.1. Descriptive analysis

The study variables are described in Table 1.

### 3.2. Parallel-process latent class growth model

The model fit indices for linear growth models and quadratic growth models are summarized in Table 2. In the linear growth models, the BIC declined as the number of classes increased, but the decline markedly slowed from the 4-class model. The LMR-LRT showed that the 4-class solution outperformed the 3-class one, whereas adding more classes no longer improved the model fit significantly. The quadratic growth models showed a similar BIC trend. The LMR-LRT between the 3-class model and the 4-class model approached significance. Then the patterns of the two models (3-class quadratic growth model vs. 4-class quadratic growth model) were compared, showing that the addition of the fourth group further revealed the heterogeneity of the data (details about the comparison are presented in the Appendix). Finally, the 4-class quadratic growth model was selected over the linear growth model due to the lower BIC.

Fig. 1 illustrates the joint trajectories of suicide rates and homicide rates in the 4-class quadratic growth model in the 20 years between 2000 and 2019. Two classes had inverse trajectories: Class 1 contained 41 countries (22.40% total sample) which experienced increasing suicide rates and decreasing homicide rates ("suicide up, homicide down": UD), whilst Class 2 included 17 countries (9.29%) which experienced decreasing suicide rates and increasing homicide rates ("suicide down, homicide up": DU). Conversely, two classes had parallel trajectories: both suicide rates and homicide rates trended up in Class 3 countries (UU, $n = 19$, 10.38%), whilst in Class 4 countries ($n = 106$, 57.92%), both rates trended down (DD). The distribution of the four trajectory classes is illustrated in the world map in Fig. 2. The country composition of each class is detailed in the Appendix.

**Table 1**
Descriptive statistics of study variables.

| | Number of the observations | *M (SD)* |
|---|---|---|
| Suicide rate (per 100,000) | 3660 | 10.63 (8.99) |
| Homicide rate (per 100,000) | 3660 | 9.15 (11.88) |
| GDP per capita baseline (current international $) | 175 | 11384.97 (15227.27) |
| Unemployment rate baseline (%) | 178 | 8.64 (6.75) |
| urban population baseline (%) | 183 | 52.10 (22.87) |
| elderly population baseline (%) | 183 | 6.77 (4.61) |
| Gini Index baseline | 146 | 39.52 (8.77) |
| GDP per capita AAGR (%) | 179 | 4.36 (2.36) |
| Unemployment rate AAGR (%) | 178 | 0.10 (3.42) |
| Urban population AAGR (%) | 182 | 0.71 (0.83) |
| Elderly population AAGR (%) | 183 | 1.12 (1.18) |
| Gini index AAGR (%) | 173 | −0.10 (0.42) |

*Note.* AAGR = average of annual growth rates.

**Table 2**
Model fit indices for linear growth models and quadratic growth models.

| | BIC | Entropy | LMR-LRT | Smallest class (%) |
|---|---|---|---|---|
| Linear growth models | | | | |
| 2-class model | 5283.98 | 0.997 | < 0.001 | 19.13% |
| 3-class model | 4960.38 | 0.972 | < 0.01 | 19.13% |
| 4-class model | 4801.11 | 0.981 | < 0.01 | 7.65% |
| 5-class model | 4758.63 | 0.979 | 0.22 | 5.46% |
| 6-class model | 4727.82 | 0.980 | 0.17 | 4.92% |
| Quadratic growth models | | | | |
| 2-class model | 5289.96 | 0.995 | < 0.001 | 19.13% |
| 3-class model | 4940.45 | 0.986 | < 0.01 | 19.13% |
| **4-class model** | **4781.53** | **0.990** | **0.06** | **9.29%** |
| 5-class model | 4742.35 | 0.984 | 0.84 | 6.01% |
| 6-class model | 4723.24 | 0.987 | 0.10 | 3.28% |

*Note.* The optimal solution is indicated in boldface. BIC = Bayesian Information Criterion, LMR-LRT = Lo-Mendell-Rubin likelihood ratio test.

### 3.3. Multinomial logistic regression

Table 3 presents the results of multinomial logistic regression ($n = 140$) based on the listwise deletion of missing cases. DU countries were more likely to have a lower AAGR of GDP per capita (OR = 0.642, 95% CI: 0.416, 0.991) than DD countries. Countries with higher AAGR of unemployment rates were more likely to be in UD and UU, compared with DD (UD vs. DD: OR = 1.196, 95% CI: 1.009, 1.417; UU vs. DD: OR = 1.245, 95% CI: 1.023, 1.514), while countries with higher AAGR of urbanization were less likely to be in UD than in DD (OR = 0.468, 95% CI: 0.231, 0.949). No other significant effects were found when the rest of the three classes served as the reference group.

## 4. Discussion

This study is the first global attempt that we know of, to explore longitudinal heterogeneity in the relationship between suicide and homicide. Our innovative application of parallel-process LCGM identified four different classes of trajectories of suicide rates and homicide rates. Our findings concurred with findings from cross-sectional studies, which identified heterogeneous relationships between these two types of violence. Suicide and homicide have long been viewed as reflections of disorganization (Durkheim, 1897/1951). Based on our findings that the DD class contained the largest number of countries ($n = 106$, 57.92%), we might conclude that over half the countries in the dataset had enjoyed a more harmonious society in the past twenty years. However, over one-third countries ($n = 58$) had inverse over-time relationships between suicide and homicide (UD or DU). The emergence of these two classes perhaps provides evidence for claims that suicide and homicide are alternative expressions of the same underlying process. They may show divergent patterns in response to the same forces. Whilst there was a relatively dispersed distribution of UD and DU across the countries in the dataset, most of the UU countries were found in Latin America. If we only focus on the homicide rates, it is obvious that this area contains most of the countries with rising homicide rates. Latin America has long been known as a land of violence and social instability. The underlying mechanisms behind these circumstances are complicated, as they can be collectively shaped by economic prosperity, rapid urbanization, weak institutions, large inequalities, and machismo cultures (Imbusch et al.,

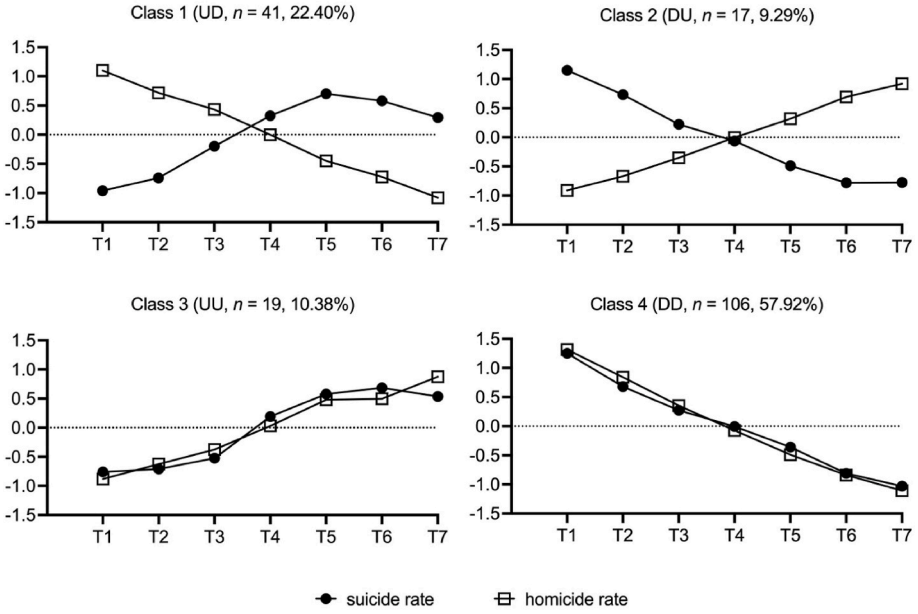


**Fig. 1.** Joint trajectories of suicide rates and homicide rates in 4-class quadratic growth model
***Note.*** UD = countries with increasing suicide rates and decreasing homicide rates, DU = countries with decreasing suicide rates and increasing homicide rates, UU = countries where both the suicide rates and homicide rates were increasing, DD = countries where both the suicide rates and homicide rates were decreasing.

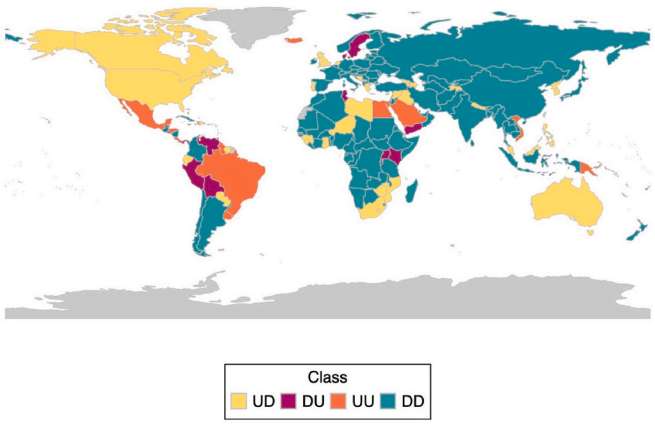


**Fig. 2.** The distribution of the four classes across the world
***Note.*** UD = countries with increasing suicide rates and decreasing homicide rates, DU = countries with decreasing suicide rates and increasing homicide rates, UU = countries where both the suicide rates and homicide rates were increasing, DD = countries where both the suicide rates and homicide rates were decreasing. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2011; Vilalta, 2020). Moreover, there are also disparities across the countries within this continent. We cannot ascribe the violence issue to a single cause. Another thing that should be noted is that although Class 1 is called UD ("suicide up, homicide down"), a decline of suicide rates was witnessed since T6 (year 2015). Class 3 UU ("both rates trended up") also experienced a slight decrease of suicide rates since T7 (year 2018). These may be attributed to the implementation of suicide prevention strategies among these countries where a rising trend of suicide had been detected. Suicide has been recognized as a public health concern in recent years. WHO issued their first report on suicide prevention in 2014, urging for coordinated action to reduce suicides globally (World Health Organization, 2014). The rise of global concern also contributed to the decline of the suicide rates.

Overall, we contend that the relationship between suicide and homicide is more complex than once thought, and it cannot be adequately explained by a single theory. According to a study based on world values survey data, the direction of violence was not related to the locus of control (Stack & Laubepin, 2017), which conflicted with the attribution style hypotheses proposed by stream analogy theory. We argue that the complexity of the relationship between the two forms of violence is derived not only from the dynamic interactions among the social, economic, and cultural factors in different countries but also from the complicated nature of suicide and homicide. As Durkheim (1897/1951) proposed, although homicide is not his primary interest, the association between suicide and homicide may not be consistent because there are four sorts of suicide 1) egoistic suicide, 2) altruistic suicide, 3) anomic suicide, and 4) fatalistic suicide.

Differences in structural covariates were found between DD, and the other three classes. Countries in UD and UU had higher AAGR of unemployment rate than those in DD. Considering that no differences were found between DU and DD, we believe that the change in unemployment rate had an effect on suicide rates, but not homicide rates. The positive relationship between unemployment and suicide has been repeatedly reported in previous studies (see Haw et al., 2015 for review). At the societal level, unemployment can be an indicator of weakened social cohesion, which further relates to suicide (Durkheim, 1897/1951). At the individual level, unemployment leads to a status of deprivation, increasing the risks of mental disorders and suicidal behaviors (Haw et al., 2015; Paul & Moser, 2009). We also found that countries with a faster urbanization process were more likely to be in DD than UD, which means the speed of urbanization was inversely associated with suicide. Mixed results have been found for the relationship between urbanization and suicide in prior studies as the situation varied across countries (Chan et al., 2015; Otsu et al., 2004; Stack, 1993, 2000). The possible mechanisms for the negative relationship include that urbanization brings more employment and educational opportunities, interpersonal interactions, and access to healthcare services (Ventriglio et al., 2021; Wang et al., 2014). Besides, consistent with the majority of available studies (see Trent & Pridemore, 2012 for review), our analysis indicated that economic development was accompanied by a decrease in homicide based on the differences we found in GDP per capita growth between DD and DU. Several explanations may account for this relationship. First, economic growth may alleviate poverty to some extent. Second,

**Table 3**
Multinomial logistic regression analysis for the associations between structural indicators and trajectory classes (n = 140).

| | UD ($n$ = 30) | | DU ($n$ = 15) | | UU ($n$ = 14) | |
|---|---|---|---|---|---|---|
| | OR (95% CI) | *p-value* | OR (95% CI) | *p-value* | OR (95% CI) | *p-value* |
| Log of GDP per capita baseline | 0.581 (0.203, 1.66) | 0.311 | 0.636 (0.171, 2.364) | 0.499 | 0.890 (0.246, 3.224) | 0.859 |
| Unemployment rate baseline | 0.983 (0.902, 1.071) | 0.688 | 0.953 (0.855, 1.063) | 0.387 | 0.947 (0.835, 1.075) | 0.403 |
| urban population baseline (%) | 1.002 (0.967, 1.039) | 0.899 | 0.992 (0.945, 1.041) | 0.746 | 1.015 (0.967, 1.067) | 0.542 |
| elderly population baseline (%) | 1.039 (0.864, 1.249) | 0.685 | 1.088 (0.864, 1.371) | 0.472 | 0.960 (0.736, 1.252) | 0.762 |
| Gini index baseline | 1.016 (0.936, 1.104) | 0.702 | 1.033 (0.927, 1.152) | 0.557 | 1.094 (0.976, 1.227) | 0.124 |
| GDP per capita AAGR (%) | 0.920 (0.678, 1.247) | 0.590 | 0.642 (0.416, 0.991) | **0.045** | 0.858 (0.540, 1.363) | 0.516 |
| Unemployment rate AAGR (%) | 1.196 (1.009, 1.417) | **0.039** | 1.053 (0.828, 1.337) | 0.675 | 1.245 (1.023,1.514) | **0.028** |
| % urban population AAGR (%) | 0.468 (0.231, 0.949) | **0.035** | 0.955 (0.395, 2.307) | 0.918 | 0.445 (0.163, 1.213) | 0.113 |
| % elderly population AAGR (%) | 1.369 (0.803, 2.332) | 0.248 | 1.804 (0.904, 3.598) | 0.094 | 1.235 (0.615, 2.482) | 0.553 |
| Gini index AAGR (%) | 0.639 (0.210, 1.947) | 0.430 | 0.253 (0.051, 1.254) | 0.092 | 0.677 (0.135, 3.406) | 0.636 |

***Note.*** The reference group is DD ($n$ = 81). UD = countries with increasing suicide rates and decreasing homicide rates, DU = countries with decreasing suicide rates and increasing homicide rates, UU = countries where both the suicide rates and homicide rates were increasing, DD = countries where both the suicide rates and homicide rates were decreasing. Bold values denote statistical significance at the $p < 0.05$ level.

increasing GDP may promote the construction of safety nets and criminal justice system (Ouimet, 2012). Thus, countries with faster GDP growth were more likely to experience a decrease trend in homicide rates.

## 5. Limitations and future directions

This study has limitations. First, due to the data availability, we were unable to further explore the relationship between suicide rates and homicide rates by demographic subgroups or by suicide typology. We may also have overlooked the inclusion of some covariates associated with the trajectory classes. According to a US study, there are gender differences in expressions of lethal violence, which may be a result of gender differences in experienced frustrations, emotional responses to frustrations, and attribution style (Batton, 2004). Therefore, gender-specific patterns may exist in the relationship of suicide and homicide rates. Future research should extend the methods of this study into a cross-national analysis, investigating how gender-related structural covariates (e.g., gender equality) influence the relationship between suicide and homicide for men, and women. In addition, a study of 70 countries showed that national culture had an influence on the direction of lethal violence, with self-expressionism or secularism orientation associated with a high suicide rate relative to homicide rate, while survivalism or traditionalism orientation associated with a high homicide rate relative to suicide rate (Chon, 2021). Compared with self-expressionism and secularism, survivalism and traditionalism typically relate to more interpersonal distrust and less tolerance of morally controversial acts and individual differences, which may encourage more violence toward others than toward oneself (Chon, 2021; Inglehart & Baker, 2000). Future study may use a larger sample to further explore how culture axis influences the trend of lethal violence. Second, our analysis was restricted to available data, as there were variations in the number of missing values in datasets obtained from different countries. This is an inevitable limitation for most ecological studies. And we should mention that the power of the results maybe attenuated by the small sample size. Third, there are inherent limitations in GMM. Model selection has always been challenging in mixture models, because the determination of the optimal number of classes, to some extent, relies on the researcher's subjective evaluation of the model fit indices. Although an automatic approach based on individual case residuals has been proposed (Marcoulides & Trinchera, 2019), this still requires systematic evaluation (Marcoulides & Trinchera, 2021). The traditional GMM is still the most common practice in identifying classes in longitudinal data. Future studies may identify opportunities for methodological improvements.

## 6. Conclusion

This cross-national study provided convincing evidence of a heterogeneous, country-dependent relationship between suicide and homicide. Over-time changes in structural factors of economic growth, unemployment, and urbanization were responsible for the heterogeneity. Future studies should take into account the subtleties in the relationship between suicide and homicide within and between countries, when attempting to interpret and explore these two forms of violence under one framework.

### Author statement

Zixu Li: Conceptualization, Formal analysis, Literature review, Writing - original draft.

Ziyi Cai: Conceptualization, Formal analysis, Writing - review & editing, Supervision.

Paul S. F. Yip: Conceptualization, Methodology, Writing - review & editing, Supervision.

### Ethics approval/Statement EA not required

Ethical approval was not required for this study, because the data it used is not collected directly from human subjects and is publicly accessible.

### Declaration of competing interest

None.

### Data availability

Data used in this study is publicly accessible.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101376.

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