Socio-economic determinants of suicide rates in transforming China: A spatial-temporal analysis from 1990 to 2015

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Summary

Background China has experienced dramatic social changes in the last three decades. This study aimed to investigate socio-economic factors related to suicide rates in China from 1990 to 2015, and examine how the impacts of these factors on suicide rates changed over time.

Methods Suicide rates in 31 provinces in mainland China between 1990 and 2015 were obtained from the Global Burden of Disease (GBD) Study 2019. Temporal-spatial modelling was applied to assess the effects of GDP per capita, urbanization, migration, employment, divorce, proportions of children and older adults on provincial overall, male and female suicide rates.

Findings The overall suicide rate in China declined from 18·1 /100,000 in 1990 to 8·6 /100,000 in 2015, with considerable spatial variation in the magnitude of decline across provinces. The protective effects of increasing in GDP per capita, and urbanization, on provincial suicide rate were strong in 1990 (log GDP: -3·56 [95% CI: -6·15, -0·96], urbanisation: -0·07 [-0·14, -0·01]), however these effects were negligible by 2015. The association between employment and suicide rates has shifted from positive to negative over the study period, while migration remained a constant risk factor for high suicide rates (0·04 [0.00, 0·09]).

Interpretation This study highlighted the dynamic effects of economic and social factors on suicide rates in the context of transforming China. To maintain further reductions in suicide rates cannot rely simply on improving people's materialistic and economic conditions. A more holistic approach to improve overall population well-being is needed.

Keywords: Suicide; China; Social-economic determinants; Spatial-temporal analysis

Introduction

In the early 1990s, suicide was a serious public health problem in China. Approximately 300,000 Chinese people died by suicide every year, which accounted for about 40% of all suicides around the world.[1] Compared with other countries, suicide in China in the 1990s displayed unique patterns: there were higher suicide rates for females than males; there was a large discrepancy between rural and urban suicide rates; pesticide poisoning was the leading suicide method, and there were relatively low rates of mental disorders amongst suicide decedents.[2−4] Since 1990, suicide rates in China, at both national and regional levels, have substantially reduced, with the national age-standardised suicide rate declining by more than 60% (from around 20 per 100,000 persons in 1990 to seven in 2017).[5−10] This

decline contributed markedly to the overall reduction of the global suicide rate.[11]

China has experienced significant economic development over the last three decades. After the implementation of economic reforms and trade liberalization,

China has become one of the world's fastest-growing economies, with the annual gross domestic product (GDP) growth averaging 9% in the last 30 years. The rapid growth has enabled China to help raise an estimated 800 million people out of poverty.[12] In addition to economic growth, there have been many social changes in the country, including rapid urbanization, massive internal migration, reform of state-owned enterprise, shifting social values, and dramatic demographic transition.[13−16]

Seminal work by Durkheim suggested that social regulations and integration are the two forces that would influence societal rate of suicide.[17] He posited that economic development, accompanied by modernization, urbanisation and migration should increase suicide rates, as development weakens social control over individuals, and disrupts traditional forms of social organization that produce cohesion. However, empirical studies in China have not fully supported this claim. For instance, research in Shandong province found that suicide rates declined during times of economic prosperity. Similarly, a study using nationwide data reported a negative relationship between GPD per capita and suicide rates.[18] Urbanisation was considered to be an important contributor to reducing suicide rates in China. In the early 1990s, there was a high rural suicide rate in China of approximately 27 per 100,000 population, with a large proportion of these suicides involving ingestion of lethal doses of pesticide.[2] Since then, suicide rates in rural areas have decreased significantly. This may be associated with the rapid process of urbanisation that has led to the shift of labour forces from agriculture to industrial and service sectors, resulting in less access to farming-related pesticides and substantial improvement of living standards.[19,20] Suicide rates in rural areas dropped by half from 1990 to 2010, this being the main driving force in the downward trend of China's overall suicide rate over that time.[5,8] However, migration was positively related to suicide rates. A study by Li et al.[21] found that villages with higher levels of social fragmentation, indicated by migration, had higher suicide rates.

Durkheim also suggested that divorce rate and the presence of children, the indicators of social integration and family ties play an important role in influencing suicide rates.[17] High divorce rates and fewer children in families weaken social integration, and thus suicide rates would be expected to rise accordingly. This claim has been supported in Western literature.[22−27] However, in China, a negative association between divorce rates and suicide rates has been found.[28] Being married also did not protect young rural females from suicide.[29]

Other factors such as the labour market situation have been associated with suicide rates,[30−32] but they are not well understood in Chinese society. Employment implies economic opportunities and security. Societies with high proportion of the employed are expected to have lower suicide rates. A study in all world

regions suggested that unemployment elevated the risk of suicide by 20−30%.[30] The impacts of demographic changes, particularly population ageing on suicide rates are worth noting. From 2000 to 2012, the suicide rates in all age groups in China declined except for the oldest adults (aged 80 years and above),[8] and the proportion of older adult suicides amongst total suicides in China has increased from 16·9% in 1987 to 41·2% in 2014.[33]

Considering the economic and societal changes in China over the past 30 years, Durkheim's suicide theory framework, and evidence from previous empirical investigations, we hypothesised that six domains of socio-economic changes may be potentially linked to the significant over-time change in China's suicide rates. The domains were economic development, urbanisation, migration, labour market situation, family change and population ageing. There have been few studies systematically investigating how over-time changes in these domains relate to changes in suicide rates in China. Previous studies have mostly focused on one or two domains of social factors, and the investigations have been limited to suicide rates at national level or in "urban-rural" categories.[6,8,18,21,28] However, China is a huge country with 1.4 billon people. There are 31 provinces located on the mainland, which are heterogeneous in terms of socio-economic development, and over-time change in suicide rates. No detailed study has investigated changing provincial suicide rates in China, taking into account their spatial patterns. Moreover, research to date has largely taken a static lens to examine socio-economic factors related to suicide, assuming that associations would remain constant over time. However, as social contexts and values in China have changed rapidly over the past three decades, the impacts of these factors are likely to change as well. This study thus aimed to take a dynamic perspective to comprehensively examine the temporal effects of six domains of socio-economic factors on suicide rates over the period 1990 to 2015, at provincial level in mainland China.

Methods

Study design
This study applied an ecological design and analysis.

dependant variables
In this study, we extracted the provincial suicide rates overall, and by sex, in each five-year interval from 1990 to 2015 (1990, 1995, 2000, 2005, 2010, and 2015) from China's Global Burden of Disease (GBD) Study 2019. China's GBD study is the result of the long-term cooperation of the Chinese Centre for Disease Control and Prevention, the Institute for Health Metrics and Evaluation and other agencies of the Chinese government that aims to systematically analyse the national and provincial level burden of disease in China.[10,34,35] By utilising large scale demographic and epidemiological datasets as well as standardised estimation methods, China's GBD study generated cause-specific mortality at province level in the past 30 years. This enables comparisons across locations and over time. In the GBD study, suicide death was identified by the International Classification of Diseases (ICD) codes: X60-X64.9, X66-X84.9, Y87.0 in ICD-9 and E950-E959 in ICD-10.[11,36] Cause of death data coded as suicide from the National Mortality Surveillance (NMS) System (combined with the China disease surveillance points system (DPS) and vital registration) was the main data source used by GBD study to estimate national and provincial suicide mortality. The details of GBD study design and modelling have been well described elsewhere.[10,11,36,37] Briefly, data for all-cause mortality in China were mapped to the GBD cause list of diseases and injuries. 'Garbage' codes or ill-defined causes of deaths were redistributed proportionally by location, year, sex, age and others through China-specific proportions statistical methods. Finally, the cause of death ensemble model (COEDm) developed for the GBD study 2019 was applied to estimate suicide mortality at provincial level. The GBD estimation has the advantage of harmonising the cause of death coding using different versions and can partially adjust for variations in data quality across time and locations.

Independent variables
We selected variables that can indicate the socio-economic changes in six domains, including economic development, urbanisation, migration, labour market situation, family change and population ageing. These variables should be available at provincial-level in each five-year interval from 1990 to 2015, and can be retrieved from reliable sources.

Provincial economic development was indicated by GDP per capita, with the data obtained from the China Statistical Yearbook (in 1990, 1995, 2000, 2005, 2010, and 2015). The level of urbanisation was measured by the proportion of urban residents in the total resident population in each province at these time points, with the data from the China Population & Employment Statistics Yearbook.

Inter-provincial migration was measured by the absolute value of the discrepancy between residential population and hukou population divided by hukou population. In mainland China, hukou is a system of household registration that demonstrates individuals' household origins. The hukou population referred to the population according to their household registration under the Ministry of Public Security, while the resident population was referred to as the population residing in a place for more than six months. A larger value of inter-province migration measure indicated a higher level of migration.

The labour market situation was indicated by the proportion of employed persons, which was calculated by the proportion of employed residents in the total resident population, aged 15 years or above. Data were extracted from the China Population & Employment Statistics Yearbook in the corresponding years. Sex-specific proportions of employment were also calculated.

Family change was indicated by divorce rates and the presence of children. Divorce rates in each province were referenced as the number of divorces per 1000 married female residents. Data on the number of divorces were extracted from the China Civil Affairs' Statistical Yearbook (in 1990, 1995, 2000, 2005, 2010, and 2015). The number of married female residents was extracted from the Population Census (in 1990, 2000, and 2010) and the China 1 per cent Population Sample Survey (in 1995, 2005, and 2015). The presence of children was measured by the proportion of children (aged under 15 years) in the total resident population, with data extracted from the Population Censuses and the China 1 per cent Population Sample Surveys.

Population ageing was indicated by the proportion of older adults (aged 65 years and over) in the total resident population. The data were obtained from the Population Censuses and the China 1 per cent Population Sample Surveys.

Analytical strategies

Our analysis contained 186 observations on suicide rates for 31 provinces at six-time points, overall, and for males and females, respectively. Suicide behaviours could be socially contagious. People contemplating suicide might adopt 'copycat behaviours' through exposure to other suicide deaths or media reports, and people living in near places might share similar cultures and beliefs, resulting in similar susceptibilities to suicidal behaviours.[38,39] Thus, it is reasonable to expect that provincial suicide rates may be spatially correlated.

To capture the effects of socio-economic factors as accurately as possible, we attempted to control the potential impact from spatial diffusion of suicide. We adopted a spatial autoregression model (SAR model) with province- and time-fixed effects (equitation shown in Appendix), because it has taken into account the spatial correlation of suicide rates, and the fixed effects approach had the capacity to remove all unobserved province- and time-specific effects. The unit of analysis in this study was the suicide rate at province level. The assumption of this model is that the suicide rate of a province is spatially clustered rather than randomly dispersed, and it is more likely to be influenced by the suicide rates of the neighbouring provinces than by provinces further away. Before applying SAR models, a test for spatial effect was conducted using Moran's I and it showed a significant positive spatial correlation. In the SAR model, a spatial weight was introduced and constructed based on the criterion of Queen contiguity, which reflects the geographic closeness of every other province to a specific province. The test of ρ statistics was used to indicate whether the suicide rate in one province was correlated to those of neighbouring provinces. To investigate how the effects of socio-economic factors changed over time, the interactions between each factor and the year (dummy) variable were added separately to the SAR models. In the SAR model with interactions, the main effect indicated the effect of the factor of interest in the reference year. We changed the reference year consecutively to obtain the marginal effects in different years. The SAR model was performed in Stata version16 using the XSMLE command.[40]

We were aware that the independent variables considered in this study might be highly correlated, thereby multicollinearity was assessed by using the variance inflation factor (VIF). The VIFs of all independent variables were less than 10, suggesting that multicollinearity would not significantly affect our estimates (shown in the Appendix).[41]

Role of the funding source

The study funders had no role in study design, data collection, data analysis, interpretation, or writing of the report.

Results

Trends of the provincial suicide rates in china

Based on the GBD data, the national suicide rate in China decreased from 18·1 per 100,000 persons in 1990 to 8·6 per 100,000 persons in 2015. Figure 1 illustrates the overall and sex-specific suicide rates in 31 Chinese provinces in 1990 and 2015. Location codes and suicide rate values are presented in Appendix Table 1A. In 1990, there was considerable heterogeneity of suicide rates across provinces. Most provinces with high suicide rates were located in the central part of China. In particular, Hubei (HUB) and Anhui (AH) province had the highest overall suicide rates, about 34·2 and 33·6 per 100, 000 respectively. Female suicide rates in these two provinces were higher than those of males (41·4/100,000 for females, and 26·4/100, 000 for males in AH; 37·7/100, 000 for females, and 31·0/100, 000 for males in HUB). By contrast, Beijing (BJ) had the lowest suicide rate, at 7.6 per 100, 000 persons. In 2015, the spatial heterogeneity of suicide rates amongst provinces has been reduced, ranging from 3·8 per 100,000 persons in Beijing (BJ) to 22·4 in Hubei (HUB). The gender pattern of suicide rates had also changed: males now had higher suicide rates than females in all provinces.

From 1990 to 2015, overall suicide rates in all provinces decreased. As shown in Figure 2, both male and
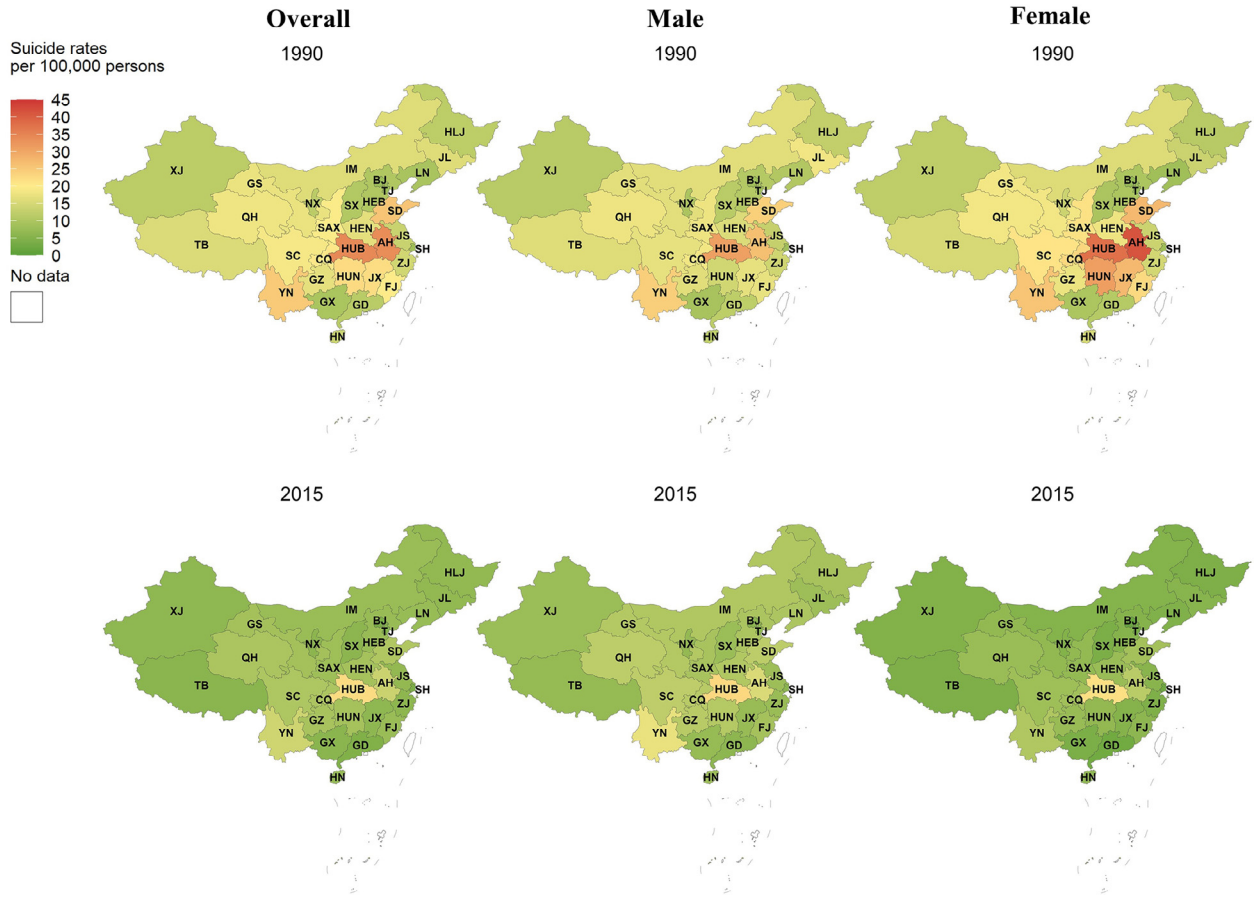
Figure 1. The suicide rates for 31 provinces in mainland China in 1990 and 2015, overall and by sex.

Variables	Overall			Male			Female		
	β	95% CI	p	β	95% CI	p	β	95% CI	p
Log GDP per capita	−1·87	(−4·07, 0·33)	0·097	−1·97*	(−3·71, −0·22)	0·027	−1·21	(−4·44, 2·03)	0·464
Urbanisation (%)	−0·05	(−0·11, 0·01)	0·099	0·01	(−0·04, 0·05)	0·804	−0·11*	(−0·20, −0·02)	0·016
Migration (%)	0·04*	(0·00, 0·09)	0·034	0·05**	(0·02, 0·09)	0·001	0·05	(−0·01, 0·11)	0·131
Employment (%)	0·00	(−0·10, 0·10)	0·950	−0·01	(−0·11, 0·09)	0·845	0·05	(−0·06, 0·15)	0·418
Divorce (‰)	0·03	(−0·26, 0·31)	0·849	−0·05	(−0·28, 0·18)	0·642	0·13	(−0·29, 0·55)	0·533
Proportion of children (%)	−0·27**	(−0·45, −0·09)	0·003	−0·21**	(−0·35, −0·07)	0·004	−0·35*	(−0·61, −0·08)	0·011
Proportion of old adults (%)	−0·14	(−0·58, 0·31)	0·549	0·27	(−0·08, 0·63)	0·130	−0·54	(−1·18, −0·10)	0·099
ρ	0·24*	(0·05, 0·44)	0·014	−0·01	(−0·23, 0·20)	0·908	0·26**	(0·07, 0·45)	0·008

Table 1: Results of the SAR models.

Notes: * P<0·05, **p<0·01, ***p<0·001. Urbanization refers to the proportion of urban residents in the total resident population. Migration refers to the absolute value of the discrepancy between residential population and hukou population divided by hukou population. Employment refers to the proportion of employed persons in the total resident population. Divorce refers to the divorce rate (per 1000 married women). The unit of change for urbanization, migration, employment, proportion of children, and proportion of old adults is 1%; the unit of change for divorce is 1‰.

female suicide rates decreased, with the larger magnitude of decrease observed for females (female suicide rates decreased by more than 40% in all provinces). Particularly, in Jiangxi (JX) province, female suicide rates declined by as much as 81%. For males, however, the greatest decrease occurred in Jilin (JL) province (by 56%), and there were only nine provinces where suicide rates decreased by more than 40%. The provincial suicide rates in each 5-year interval from 1990 to 2015 are illustrated in the Appendix (Figure 1A-3A).

Factors affecting provincial suicide rates over the period from 1990 to 2015

Table 1 presents the results of the SAR model that examined the impacts of study factors on suicide rates (log GDP per capita, urbanisation, migration, employment, divorce, proportion of children and old adults). The spatial autocorrelation coefficients ρ for the overall suicide rates and female suicide rates were 0·24 (95% CI: [0·05, 0·44], $p < 0.05$) and 0·26 (95% CI: [0·07, 0·45], $p < 0.01$), respectively. This indicates a significantly positive spatial dependency. In other words, the rise of suicide rates overall, or for females in neighbouring provinces, increased the corresponding suicide rates in the reference province. After adding all proposed factors in the model and controlling for the spatial autocorrelation of suicide rates, we found that log GDP per capital was negatively associated with male suicide rates ($\beta = -1.97$, 95% CI: [−3·71, −0·22], $p < 0.05$). This meant that if GDP per capita increased by one percent, male suicide rates would decrease by 1·97 per 100,000 persons. Urbanisation was negatively associated with female suicide rates ($\beta = -0.11$, 95% CI: [−0·20, −0·02], $p < 0.05$), interpreted as one percent increase of urban population would result in a decrease of female suicides of 0·11 per 100,000 persons. We also found that in provinces with higher level of migration, there were higher overall suicide rates ($\beta = 0.04$, 95% CI: [0·00, 0·09], $p < 0.05$) and male suicide rates ($\beta = 0.05$, 95% CI: [0·02, 0·09], $p < 0.01$). The proportion of children in the population was negatively related to overall suicide rates ($\beta = -0.27$, 95% CI: [−0·45, −0·09], $p < 0.01$) and both sex-specific suicide rates (male: $\beta = -0.21$, 95% CI: [−0·35, −0·07], $p < 0.01$; female: $\beta = -0.35$, 95% CI: [−0·61, −0·08], $p < 0.05$).

Changing relationships between factors and suicide rates over time

Table 2 illustrates the coefficients of the interaction terms in the SAR models. The coefficients of the interactions with log GDP per capita and urbanisation increased gradually over time for overall and female suicide rates, and most of them remained significant after 2000. By contrast, the coefficients of the interaction with employment decreased over time for both males and females, and for males, this pattern was more
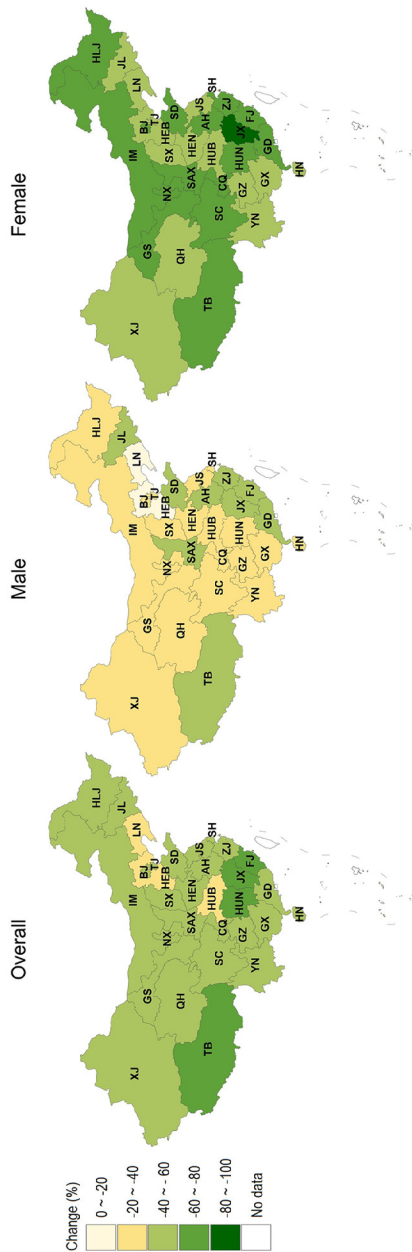
salient. There was a significant interaction between divorce and female suicide rates in 2015, as well as significant interactions between the proportion of children in the population and female suicide rates in 2005 and 2015. For migration and the proportion of older adults in the population, no significant time interactions were found (results not presented in the table, but available on request).

Based on the results of the regression models shown in Table 2, marginal effects of these factors were illustrated in Figure 3. This shows that the protective effect of GDP per capita on suicide rates was strong in 1990 ($\beta = -3.56$, 95% CI: [-6.15, -0.96], $p < 0.01$) but reduced over time and became insignificant since 2000. Similarly, the contributory role of urbanisation in reducing female suicide rates has decreased over time. In 1990, urbanisation increased by one percent, female suicide rates would decrease by 0.15 per 100, 000 persons. However, in 2015, one percent increase in urbanisation increased female suicide rates by 0.02 per 100, 000 persons, although this positive association hasn't reached the significant level. We observed that employment had a positive association with suicide rates in 1990 ($\beta = 0.19$, 95% CI: [0.02, 0.36], $p < 0.05$). However, this association had reversed by 2015. Although no significant association between divorce and suicide rates was observed from 1990 to 2015, its role in affecting suicide, specifically for females, changed significantly. In 1990, divorce tended to decrease female suicide rates while it was likely to increase female suicide rates in 2015. The proportion of children showed stable protective effects on male suicide rates, while its protective effects on female suicide rates became stronger over time. The coefficients of the association between proportion of children and female suicide rates changed from -0.07 in 1990 to -0.46 in 2015.

Discussion

Main finding

This study, to the best of our knowledge, is the first that reports on an investigation of provincial suicide trends in mainland China. Suicide rates in all provinces, especially female suicide rates, decreased substantially from 1990 to 2015. Suicide was spatially contagious: an increase of suicide rates in one province appeared to diffuse into neighbouring provinces. Economic development, urbanisation, migration, and the presence of children were important determinants of suicide rates across provinces during the whole study period but there were sex-specific effects. We also found that the effects of economic development, urbanisation, employment, divorce, and presence of children were neither constant nor static. The magnitude and even direction of their effects on suicide rates changed at different time periods.

Figure 2. Percentage change of suicide rates in 31 provinces in mainland China from 1990 to 2015, overall and by sex.

	Overall			Male			Female		
	β	95% CI	p	β	95% CI	p	β	95% CI	p
Log GDP per capita									
Main effect	−3·56**	(−6·15, −0·96)	0·007	−2·92**	(−5·02, −0·83)	0·006	−4·05*	(−7·87, −0·24)	0·037
Interaction with time (Ref: year 1990)									
Year 1995	0·46	(−1·00, 1·92)	0·535	0·50	(−0·70, 1·70)	0·412	0·67	(−1·43, 2·77)	0·533
Year 2000	1·87*	(0·27, 3·48)	0·022	1·33	(0·00, 2·66)	0·051	2·97*	(0·69, 5·26)	0·011
Year 2005	2·39**	(0·77, 4·01)	0·004	1·34*	(0·03, 2·66)	0·045	3·79**	(1·44, 6·14)	0·002
Year 2010	2·42**	(0·61, 4·22)	0·009	0·92	(−0·53, 2·37)	0·213	4·13**	(1·48, 6·78)	0·002
Year 2015	2·46*	(0·40, 4·53)	0·019	0·29	(−1·35, 1·94)	0·728	4·49**	(1·49, 7·49)	0·003
Urbanisation (%)									
Main effect	−0·07*	(−0·14, −0·01)	0·032	0·00	(−0·06, 0·05)	0·889	−0·15**	(−0·25, −0·05)	0·002
Interaction with time (Ref: year 1990)									
Year 1995	0·01	(−0·03, 0·05)	0·738	0·01	(−0·03, 0·04)	0·679	0·01	(−0·05, 0·07)	0·644
Year 2000	0·04	(−0·01, 0·09)	0·082	0·03	(−0·01, 0·07)	0·169	0·08*	(0·01, 0·14)	0·027
Year 2005	0·06*	(0·01, 0·12)	0·016	0·03	(−0·01, 0·07)	0·137	0·11**	(0·03, 0·18)	0·004
Year 2010	0·07*	(0·01, 0·13)	0·016	0·02	(−0·02, 0·07)	0·322	0·13**	(0·04, 0·21)	0·003
Year 2015	0·09**	(0·03, 0·16)	0·007	0·02	(−0·03, 0·08)	0·404	0·17**	(0·07, 0·26)	0·001
Employment (%)									
Main effect	0·19*	(0·02, 0·36)	0·033	0·26*	(0·02, 0·51)	0·035	0·12	(−0·02, 0·27)	0·093
Interaction with time (Ref: year 1990)									
Year 1995	−0·03	(−0·18, 0·11)	0·655	−0·11	(−0·32, 0·09)	0·279	0·02	(−0·11, 0·15)	0·736
Year 2000	−0·16*	(−0·31, −0·01)	0·039	−0·25*	(−0·47, −0·03)	0·026	−0·08	(−0·22, 0·05)	0·225
Year 2005	−0·19*	(−0·36, −0·02)	0·029	−0·23*	(−0·46, −0·01)	0·045	−0·12	(−0·27, 0·03)	0·129
Year 2010	−0·22*	(−0·41, −0·03)	0·025	−0·24	(−0·50, 0·01)	0·064	−0·15	(−0·33, 0·03)	0·098
Year 2015	−0·34***	(−0·53, −0·15)	<0·001	−0·38**	(−0·63, −0·12)	0·004	−0·26**	(−0·44, −0·08)	0·006
Divorce (‰)									
Main effect	−0·12	(−0·45, 0·20)	0·466	−0·13	(−0·40, 0·13)	0·322	−0·08	(−0·56, 0·40)	0·739
Interaction with time (Ref: year 1990)									
Year 1995	−0·14	(−0·40, 0·13)	0·305	−0·08	(−0·29, 0·14)	0·477	−0·18	(−0·57, 0·21)	0·354
Year 2000	0·17	(−0·15, 0·49)	0·299	0·13	(−0·13, 0·38)	0·336	0·27	(−0·20, 0·74)	0·261
Year 2005	0·14	(−0·14, 0·43)	0·325	0·10	(−0·13, 0·33)	0·382	0·20	(−0·23, 0·62)	0·359
Year 2010	0·21	(−0·06, 0·48)	0·132	0·11	(−0·11, 0·33)	0·316	0·29	(−0·10, 0·69)	0·142
Year 2015	0·30*	(0·01, 0·58)	0·044	0·16	(−0·07, 0·39)	0·173	0·44*	(0·01, 0·86)	0·043
Proportion of children (%)									
Main effect	−0·13	(−0·38, 0·12)	0·316	−0·19	(−0·39, 0·00)	0·054	−0·07	(−0·43, 0·30)	0·722
Interaction with time (Ref: year 1990)									
Year 1995	−0·03	(−0·22, 0·16)	0·788	0·00	(−0·15, 0·15)	0·996	−0·07	(−0·35, 0·21)	0·627
Year 2000	−0·14	(−0·34, 0·05)	0·152	−0·10	(−0·25, 0·06)	0·241	−0·23	(−0·51, 0·05)	0·103
Year 2005	−0·18	(−0·38, 0·02)	0·075	−0·09	(−0·25, 0·07)	0·267	−0·30*	(−0·59, −0·01)	0·043
Year 2010	−0·12	(−0·33, 0·09)	0·260	0·01	(−0·16, 0·18)	0·890	−0·27	(−0·58, 0·04)	0·088
Year 2015	−0·15	(−0·40, 0·11)	0·257	0·08	(−0·11, 0·28)	0·394	−0·39*	(−0·77, −0·01)	0·043

Table 2: **Interactions of the socio-economic factors with time based on the SAR models.**
Notes: * P<0·05, **p<0·01, ***p<0·001. The interactions between factor of interest and time dummy were added separately into the SAR models. Other factors were included in the models as the control variables.

Our findings showed that economic development in China from 1990 to 2015 led to a decline of suicide rates. This result was consistent with many previous studies in China, suggesting that developing the economy to reduce poverty also reduces suicide rates. Besides, the rapid urbanisation has benefited females in
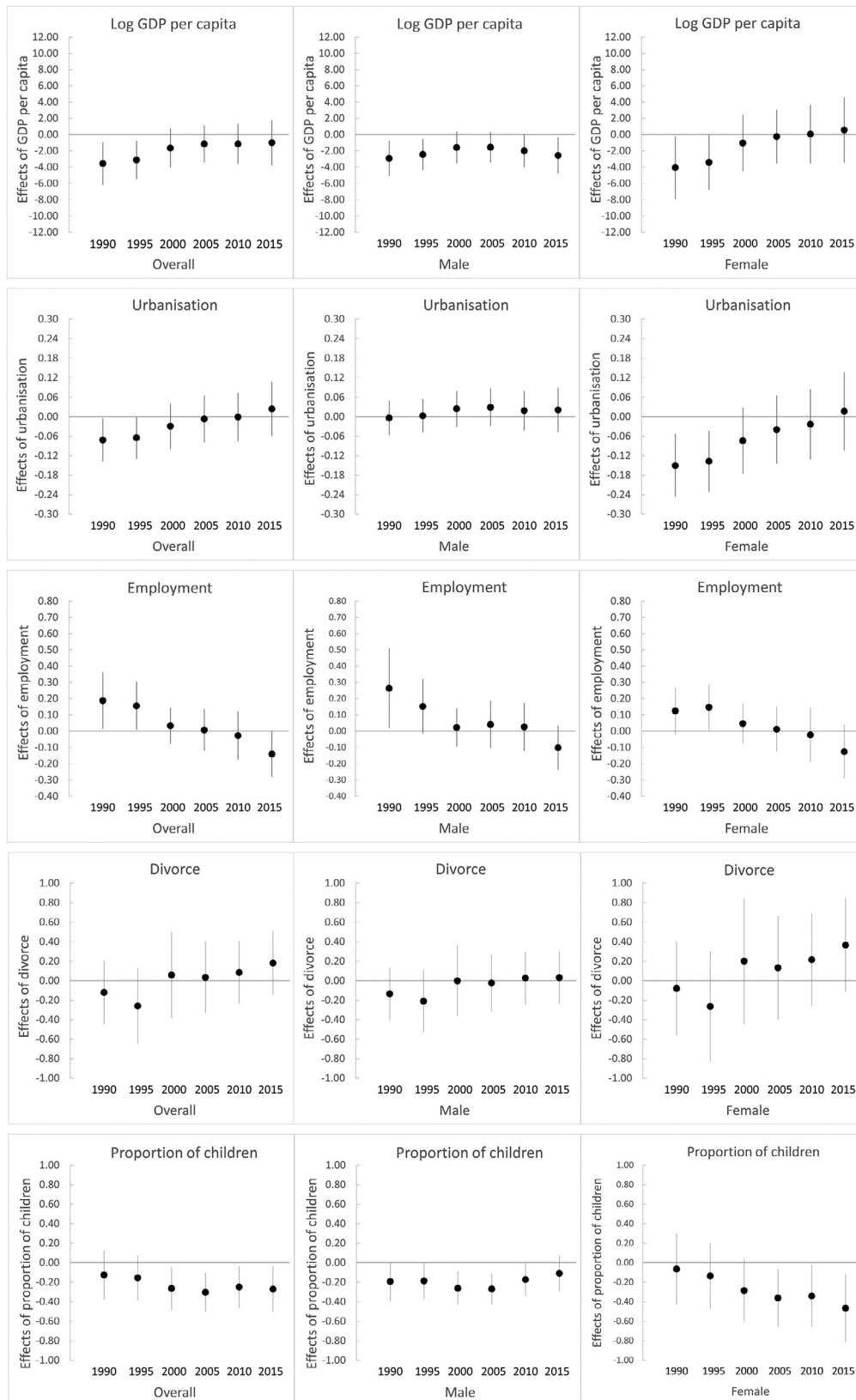
Figure 3. Marginal effects of GDP per capita, urbanisation, employment, divorce and proportion of children, based on Table 2.

terms of reducing suicide rates. In the early 1990s, China was notorious for its high female suicide rates in rural areas. This was largely explained by limited opportunities, domestic violence and family abuse, as well as easy access to lethal pesticides.[2,4,42,43] However, with acceleration of urbanization, more and more rural women who used to be confined to traditional family roles and farming lives, now had opportunities to receive education and participate in labour force markets that could help them escape from rural poverty and family conflicts. Urbanisation also reduced access to pesticides, an accepted and frequently used suicide method amongst rural females.[2,20] Consistent with previous studies in other countries, we found that the presence of children, an indicator reflecting vigour and unity of the family, has a protective effect on suicide in China. By contrast, migration was found to be a risk factor: higher levels of migration led to higher suicide rates, particularly for males. This supported Durkheim's theory, suggesting that migration might disrupt institutional continuity and existing social networks, thus reducing social integration and subsequently increasing the risk of suicide.[17,21,44,45] The adverse effect of migration was larger for males, which concurs with other studies reporting that males were more likely to be affected by the disruption of social integration.[46,47] Although previous studies have reported that older adults had the highest suicide rate compared with other age groups in China,[1,5,9,28] we did not find a significant association between the proportion of old adults and all-age suicide rates, which may suggest that the changing age structure of the population has yet significantly influenced overall change of suicide rates in China.

We note that the impacts of some socio-economic factors for suicide changed in the context of a rapidly transforming China. Although economic development and urbanisation have contributed to a substantial decline of suicide rates, our findings indicate that their beneficial effects have decreased over time. This implies that once people's living standards have reached a subsistence level, further improvements in materialistic and economic conditions may have a smaller effect on well-being—the diminishing marginal return of economic prosperity. Besides, the association between employment and suicide rates has changed significantly in the past 25 years. In the 1990s, employment was associated with high suicide rates, which might be due to high levels of stress that working people experienced, especially males who traditionally assumed the family breadwinner role. However, in recent years, employment has become a protective factor on suicide. Since the state-owned enterprise reforms, the "Iron Rice Bowl" guarantee of lifetime employment in the labour market was abolished, triggering massive layoffs of employers working in state-owned companies. The labour market in China now is more market-orientated and competition amongst job seekers has significantly increased.[48] Being employed means

economic security, becoming a crucial factor in maintaining well-being and protecting people from suicide.[49] The adverse impact of divorce on increasing suicide rates amongst females has emerged over time, whilst the protective effect of the presence of children has become stronger. This indicates that family cohesion and support are playing an increasingly important role in reducing female suicide rates.

Limitations

We acknowledge limitations that might constrain interpretations of our findings. First, this is an ecological study using provincial data, and thus the findings should not be interpreted at an individual level. Second, some socio-economic effects on suicide may be age specific. However, we could not identify these effects as we applied all-age suicide rates. Third, some important factors such as Gini index, limits of access to lethal means, improvement of medical and mental care services may potentially affect suicide rates but they cannot be investigated in the current study due to the data availability. However, some of these factors may be closely related to the level of urbanization. Cultural factors such as the acceptability of suicide may also play a role but was not covered in this study. Previous research has suggested that suicide was more likely to occur if it was viewed as a culturally acceptable way for individuals to respond to hardship.[42,50] Qualitative research may be needed to explore whether culturally-specific factors may operate in some provinces with high suicide rates. Another limitation is the quality of suicide data. The data used in this study was extracted from the GBD study in China that estimated the population distribution of deaths by cause at national and province levels. As the NMS system was the main data source for GBD study to estimate suicide mortality, the accuracy of estimations was subject to the quality and reliability of suicide data from this system. The data quality in the NMS system might be less than ideal in the early years due to the limited number of surveillance points, manual data management and the lack of strict auditing and reviewing procedures. Although the GBD study team applied a series of methods that include data standardisation and redistribution of 'garbage' codes to adjust for variations of data quality across time and locations, how much of this can be addressed remained unknown.

Policy implications

In the past three decades, rapid economic growth and urbanization in China has contributed significantly to reducing suicide rates. However, the ongoing trajectory of China's suicide rates is difficult to determine. We anticipate that further economic development and urbanisation in China might not necessarily lead to an ongoing decrease in the country's suicide rates. By contrast, the drawbacks of economic advances and

modernisation lifestyles, such as income inequality, lack of job security, role conflicts and family separation due to migration may adversely affect people's mental health, thus offsetting any advantageous effects that economic development and urbanisation have had to date, on suicide rates. How to cope with new social problems brought by the rapid social and economic changes in China is a key component of future suicide reduction strategies. The changing roles of economic development and urbanisation observed in our study provide important information for policymakers in China, as well as other low-and middle-countries. The effects of economic prosperity on reducing suicide rates may be limited to the early stages of economic development. When economic development reaches a certain level, efforts to improve overall well-being amongst population, such as launching comprehensive mental health campaigns and improving social safety nets deserve more attention.

Conclusion

This study reports the over-time effects of socio-economic factors on provincial suicide rates in mainland China between 1990 and 2015. The initially protective effects of economic development and urbanisation on suicide rates have diminished over time, while the roles of employment and family ties (indicated by marital stability and presence of children) in protecting suicide have increased. Internal migration has been a significant risk factor for suicide over the past 25 years. While maintaining socio-economic development in China, the promotion of population wellbeing economically and socially in a rapidly changing society appears to be the key to sustainably reducing China's suicide rates into the future.

Editor note
The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

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Data sharing statement
Suicide data can be obtained through the IHME website on request (http://ghdx.healthdata.org/ihme_data).

Supplementary materials
Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lanwpc.2021.100341.

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