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The effects of MDR-TB Treatment Regimens through Socioeconomic and Spatial characteristics on Environmental-Health Outcomes: Evidence from Chinese Hospitals

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Abstract

This study examines socioeconomic and spatial factors and its influences on the outcomes of environmental-health through "multi-drug resistance tuberculosis" (MDR-TB) treatment regimes in China. For this purpose, a survival analysis is conducted by applying "multivariable Cox Proportional Hazard model" on secondary data starts from 2010 to 2019. The data set is consisting of six hundred and fifty five (655) TB patients from different hospitals of China. The findings of

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this study indicate us that there is no alteration in patient survival rates between the two treatment departments, hospital and ambulatory care. The spatial characteristics of time expenditure and medical expenditure are significantly correlated with "supporting distance bias methods" and "environmental health results". On the other side, travel expenditures and male gender results show negatively associated with the "environmental-health outcome". This study reveals with these remarks that Ministry of Health, China should take serious actions to control MDR-TB and launch a comprehensive policy with the help of WHO recommendation.

Keywords
MDR-TB, environmental-health outcome, socioeconomic and spatial factors, survival analysis, china
JEL Classification: C82, I27, C13

1. Introduction

"Tuberculosis" (TB) is considered as one of the main ten (10) reasons for death worldwide as relatively compare to particular toxic agent (higher than HIV/AIDS). It is noted that there were assessed ten (10) million new instances of TB and 1.2 million people died from the disease in 2018. The high commonness of TB is consistently a severe social medical issue in China. Meanwhile, China has the second most noteworthy number of instances of TB on the globe just after India, with 866,000 cases reported in 2018 (WHO 2019).

Approximately 400,000 new cases of "multidrug-resistant tuberculosis" (MDR-TB) are observed globally each year, of which at least one of the two most effective "first-line anti-tuberculosis drugs, isoniazid or rifampin" is observed resistance generally.[1] In accordance with global trend, multi drug resistance tuberculosis has also become a major problem in China.[2] Singh et al.[3] and Oliver et al.[4] found that the "prevalence rate of MDR-TB" among new patients was 3.1%, compared with 10% among patients who have been treated globally.[5] The World Health Organization[1] has attracted people's attention, that is, "first-line drugs" have failed for many years worldwide, while second-line drugs are more expensive and less effective[6] this situation make a main challenge for the department of health in multiple countries.[7] Therefore, the treatment expenditure also involves non-medical expenditure i.e. transportation and income losses etc. along with the medical expenditure.[8,9]

Wei, et al.[10] used survey data of Chinese hospitals, differentiate the practice of various hospital on tuberculosis control models.

The objective of this research is to determine and analyze population size, socioeconomic, spatial and policy-related characteristics of MDR-TB patient's treatment regimes in China. The spatial impact is captured by time and travel expenditure on the commute to health facilities encompassing the non-medical domains affecting the treatment outcome. The availability of health facility in the nearby location and low expense on commute is expected to reduce the burden for patients and family members leading to adherence to treatment. The policy related variable is the provision of two treatment arms i.e. ambulatory and hospital care arms. As explained above, the policy makers are trying to analyze the feasibility of shift towards the ambulatory care. Various environmental, "socio-economic, socio-cultural and biological factors" influences the "health status" of people residing in China and belonging to different social groups. Some differences in health status are caused by natural factors, namely genes and old age, but many of them are related to socioeconomic differences. The socio-economic burden on patients in seeking treatment, spatial factors and selection of treatment arm play important roles in determining the outcome of treatment for different diseases. The rest of the study is organized as follows as: Section 2 explores the China's Environmental and Health Concerns, section 3 looks at the literature, section 4 examines the methodology, section 5 analyze the empirical results and section 6 concludes the research.

2. China's environmental and health concerns

In recent years, China has begun to counter the consequences of environmental pollution more strongly. Because of its geographical position, China is one of the economies where climate brake down has become more noticeable and popular. As Illustrated in Figure 1, various environmental contaminants such as carbon dioxide (CO2), GHG, nitrous oxide and methane can be present in the air. Meanwhile, GHG and CO_2 emissions per capita have risen in the region, while other gas emissions have remained constant but at a high level. Figure 2 depicts CO_2 emissions from a numerous of causes as a "percentage of total fuel combustion".

The main sources of CO_2 emissions in the atmosphere are liquid fuels and gaseous. Along with reducing air quality, environmental pollution causes increased misery at a cost of $7 to $14 billion in socio-economic costs (ESP 2019-20). Figure 3 depicts the population's exposure to PM2.5 levels of suspended air contaminants such as nitrates, sulphate and carbon all of which have a negative effect on human health. Haze and Low visibility are also caused by high concentrations of these contaminants. Even though there have been decreases in PM2.5 exposure over time, the average exposure is still very huge (See: Figure 3).

China has developed a robust air quality management system focused on an urban air quality monitoring network over the last four decades. In the 1970s, China began monitoring air quality in a less cities, and in the 1980s, it developed an initial national monitoring framework. The daily Air Pollution Index (API) was implemented in 2000 to assess air quality in 42 cities based on PM10, NO2 and SO2 monitoring data. However, PM2.5 is the largest pollutant in these urban areas, resulting in poor air quality. Bad air quality causes health problems such as a number of respiratory disorders such as cardiovascular and tuberculosis diseases, and trouble breathing, asthma. This demonstrates that the government must take significant measures to enhance air quality by lowering PM2.5 levels in order to meet the WHO's TB-free environment goal (2013).

3. Literature review

A "disease-free environment" is essential for a "healthy population", and a healthy population in turn provides a "healthy workforce" and "increases productivity". Many researchers are exploring the domain of health economics to develop the inter-linkages between health, socio-economic and spatial indicators. The development frameworks that encompass the domains of health and economics have gained importance over the time.

3.1. Socio-economic perspective

This gradient is enormous when different segments of the society are compared in a country.

The 'social support' argument proposes that informal networks are key instrument in improving the welfare of the society but they are often neglected.[11]

The polarization theory was expanded by incorporation of theories of "growth poles and growth center" in the spatial context during 1960s and 1970s.[12]

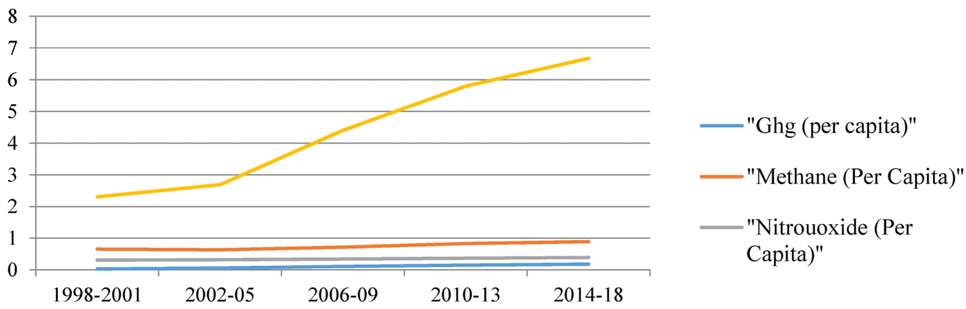

Figure 1. Gases emissions in China. Source: Author's Calculation.

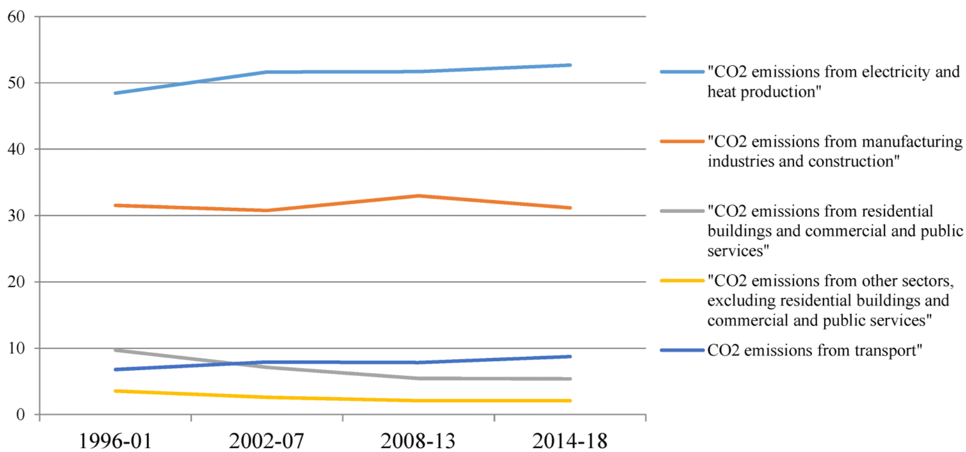

Figure 2. CO_2 emissions (as a percentage of total fuel consumption). Source: Authors Calculation.

3.2. Social Inequality perspective

The differential in the health status of the individuals (or group) is called as health inequality and the avoidable differences in health based on the race or ethnicity that can be controlled is termed as health inequity.

The 'income inequality hypothesis' proposes that the differential in the health status of individuals are associated with income inequality prevailing in an area of residence along with the level of own income.[13]

4. Methodology

The survival analysis is conducted by applying "multivariable Cox Proportional Hazard model" on secondary data starts from 2010 to 2019. The data set is consists of six hundred and fifty five (655) TB patients from different hospitals of china. Patients have been recently determined to have MDR-TB and are 12 years of age or older are eligible to participate. For the most part of the study period, patients presented an unreliable stream of data, which led to exclusion. Finally, six hundred and fifty five (655) TB patients are included in the final study based on the accessibility of applicable data.

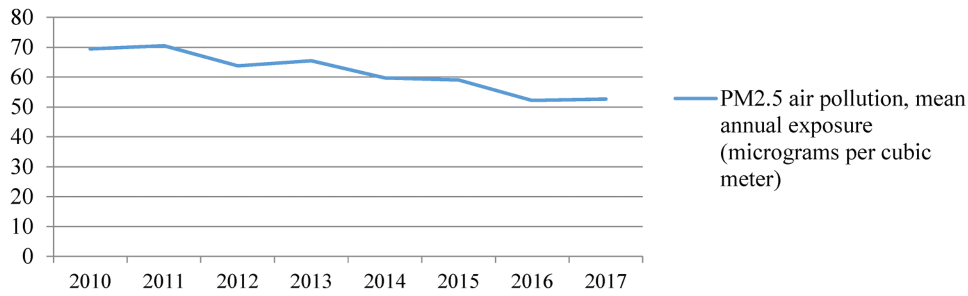

Figure 3. Pm2.5 air pollution, mean annual exposure in China. Source: WDI.

Another issue exist that all the patients would not enter the study at the same time period known as staggered entry. Some of the patients are diagnosed with the disease by the start of the study period and some develops the disease later on hence the entry point of the patients varies in the study. There are multiple treatment outcomes that can be experienced by the patient. TheWHO[14] has declared treatment outcomes as cured, completed, died, lost to follow-up, failed to recover, not evaluated till the end of study and still under treatment.[1] Cured means "a patient whose sputum smear or culture is positive at the beginning of the treatment but who is smear- or culture-negative in the last month of treatment and on at least one previous occasion". Treatment completed refers to "a patient who completed treatment but who does not have a negative sputum smear or culture result in the last month of treatment and on at least one previous occasion". Treatment failure is "a patient whose sputum smear or culture is positive at five (5) months or later during treatment". Default means "a patient whose treatment is interrupted for two (2) consecutive months or more" and died refers to "a patient who died for any reason during the course of treatment".

4.1. Empirical model

Several medical and non-medical factors together influence the health outcome. As presented in equation 1, we use our model to assess the relationship between "health policy", "demographic, spatial" and "socio-economic factors" on the environmental-health effect.

$$Environmental - health\ outcome = f\begin{pmatrix} Health\ Policy\ variables,\ \ Demographic\ factors, \\ Spatial\ factor,\ \ Scio - economic\ factor \end{pmatrix} \quad (1)$$

Where, socio-economic variables are medical expenditure, education and family income. The patient education is a significant social indicator that might have a task to perform in thoughtful of healthy environment and importance of cure along with other factors such as gender and age. Along with, demographic factors are represented by gender and age of the MDR-TB sufferers in the presented model. The demographic factor of sex is unconditional factor set equivalent to 0 for female and one for male. Also, spatial factors are obtained through time and travel spending. The clinical and the non-clinical uses make extra weight on the family's financial plan as alongside the subsidizing of costly medicines and prescriptions, they need to bear extra cash based use.

Therefore, In order to analyze the effects of MDR-TB treatment regimens through socioeconomic and spatial characteristics on environmental-health outcomes this study, rewrite equation

(1) and built up the empirical model established on the theoretical foundations as:

$$Environmental - health\ outcome = \gamma_0 + \gamma_1\ Age + \gamma_2 Gender + \gamma_3\ Education + \gamma_4 Family\ income + \gamma_5 Medical\ Expenditure + \gamma_6 Travel\ expenditure + \gamma_7 Time\ expenditure + \gamma_8 Treatment\ Arm + \varepsilon \quad (2)$$

The age of the "MDR-TB sufferers" is used as a continuous variable in the quantity of years. The education factor is used as quantities of long periods of schooling of the sufferers. Family pay is characterized as absolute pay of family is fractionalized by number of families of the "MDR-TB sufferer".

In our research model, the treatment group is used as a strategy variable, such as the ambulatory and hospital consideration group, as an unconditional variable in the treatment group, where ambulatory care is equal to 0, and the hospital consideration group is equal to 1.

This study uses the Cox Snell residuals to see if the model is effectively fitted.[15] The residuals will not display any particular pattern if the model matches correctly, and zero intercept of straight line and a unit slope will appear. Cox Snell residue within martingale residuals is used to verify the evidence of true functional type and the demand for covariate conversion.[16] The lack of any particular pattern in the figure indicates that the functional pattern is adequate and that no covariate modification is needed.[17]) To classify outliers, the martingale residuals are converted into deviance.[16]

5. Empirical results

Before analyzing our research, we conducted different demonstration tests in the research to check the credibility of the model and results. Cox Snell residuals indicate that the model is very suitable for the reference line of Nelson Aelon cumulative hazards depicted by the 45-degree line (See: Figure 4 and Figure 5). Meanwhile, summary statistics of our sample data and characteristics of patients are also given (See: Table 1 and Table 2).

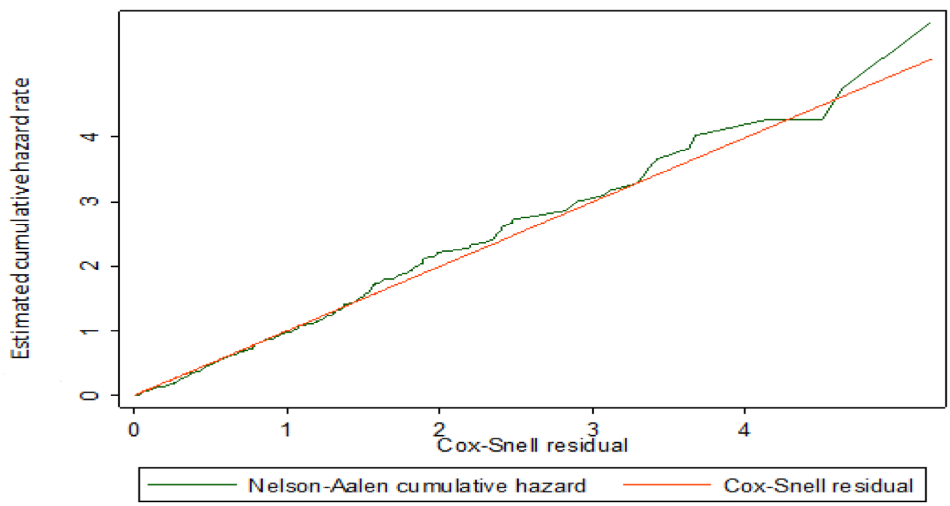

Figure 4. Cox-Snell residuals for the Cox proportional hazard model.

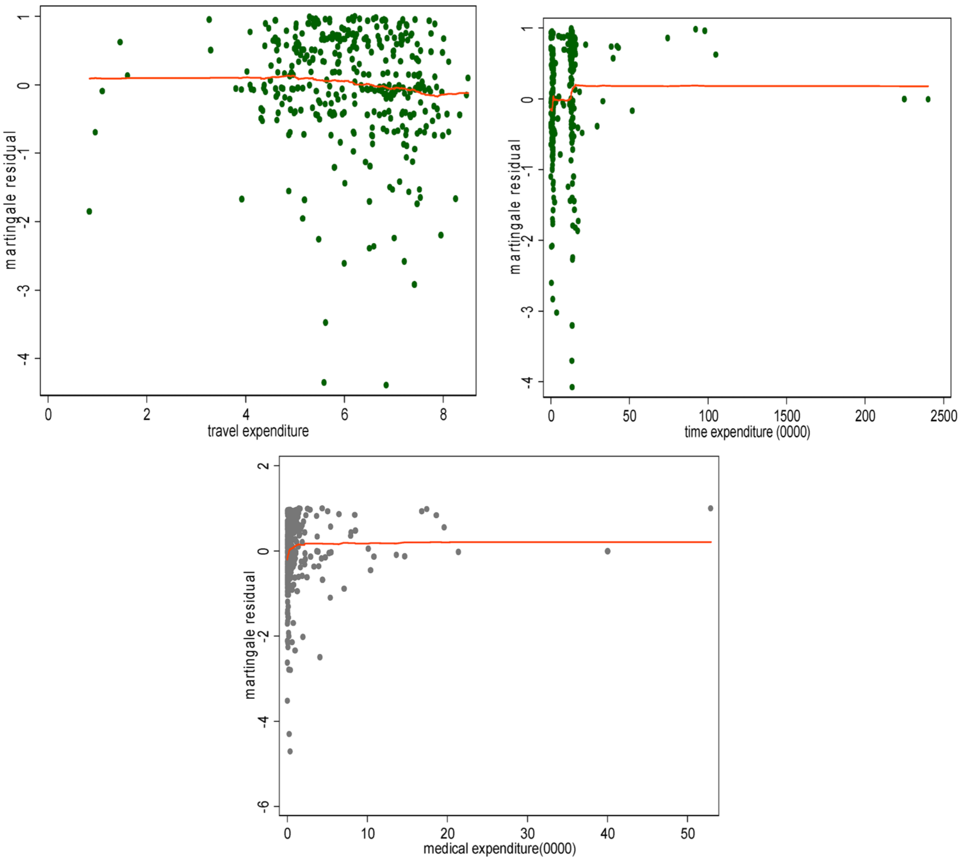

Figure 5. Martingale residuals of the covariates.

Since the findings of the proportionality assumption test demonstrate that all variables either collectively or individually are significant, we cannot dismiss the null hypothesis that the proportionality assumption holds in our model at the rate of 5% level of significance (See: Table 3). Whereas, outcomes of the backward elimination process is appeared in the Table 4.

In our sample, patients' educational status had no significant relationship with the length of time they were healed. One possible explanation for this outcome is that medical professionals are capable of providing significant information to sufferers and their families about the importance of adhering to treatment and administering drugs on time, and the degree of formal training probably won't assume a significant part (likewise see[18]).

The environmental health impact on cure rate of sufferers in our study sample is 78.24% (See: Table 1). The general treatment achievement rate for example completed and cure is 77.51% covered by the undesirable environmental situation which misses the mark concerning the ideal objective of 75-90%.[19] In addition cure rate for male sufferers is 77.12% and 82.13% for female sufferers (See: Table 2). Female cured patients show more noteworthy cure rate than male patients. The average duration of healing is more prominent for cured sufferers when contrasted with censored ones in our study. This shows that more thorough responsibility with lots of follow up appointments according to the guidance of the specialists can have improve the cure result in

Table 1. Summary statistics of data.

Outcomes	All Patients	Females Patients	Males Patients
Cured	450 (78.24)	260 (45.86)	190 (58.14)
Died	116 (7.67)	72 (57.13)	44 (48.88)
Failed	31 (3.98)	20 (49.45)	11 (56.55)
loss to follow up	37 (9.13)	19 (24.33)	18 (76.67)
still under treatment	11 (2.08)	5 (26.00)	6 (77.00)
Completed	6 (0.32)	2 (0.00)	4 (100)
not evaluated	4 (2.63)	2 (17.67)	2 (85.33)
Total	655	380 (57.72)	275 (42.28)

Table 2. Summary statistics of the characteristics of patients.

Patients characteristics		All patients	Cured	Censored
Gender	Male	349 (53.7)	230 (35.11)	119 (18.17)
	Female	306 (46.71)	180 (27.48)	126 (19.23)
Age	≤14	9 (1.37)	5 (0.763)	0 (0)
	15-36	204 (31.14)	140 (21.37)	64 (9.77)
	37-59	290 (44.27)	170 (25.95)	120 (18.32)
	≥60	152 (23.20)	90 (13.74)	64 (9.77)
Arm	Hospital care	351 (53.58)	245 (69.74)	106 (30.26)
	Ambulatory care	304 (46.41)	209 (68.76)	95 (31.24)
Education	Illiterate	252 (38.81)	160 (76.27)	92 (23.73)
	Secondary school	233 (35.41)	140 (77.16)	93 (22.84)
	Higher education	170 (25.74)	105 (74.29)	65 (25.71)

any event, when the ecological conditions are very little positive. Level of cure is less in more seasoned patients (matured at least 46 years) and more controlling is capable by them in our analysis.

Table 3. Results of test of proportionality assumption.

Covariates	DF	Chi-Square	Prob>chi2
"Gender"	1	1.82	0.21
"Travel expenditure"	1	1.12	0.4
"Time expenditure"	1	0.62	0.52
"Medical expenditure"	1	1.62	0.24
"Global Test of proportionality"			0.22

Table 4. Variable selection through backward elimination process.

	Z-statistics				
Variables	Step 1	Step 2	Step 3	Step 4	Step 5
Age	0.75	D	D	D	D
Family income	−0.79	−0.85	D	D	D
Education	−0.13	D	D	D	D
Arm	1.15	1.15	1.16	D	D
Gender	−1.97	−1.96	−2.97	−3.03	−2.10
Medical expenditure	4.68	4.65	4.98	4.99	4.81
Travel expenditure	−1.79	−1.76	−1.73	−1.66	−1.79
Time expenditure	4.99	5.01	4.98	5.03	5.20
Note: D shows that vales are dropped					

The undesirable air quality and immunity level decreases are the determinants of their low cure ratios. In our analysis, 100% have a place with the age gathering of at least 14 years, 15-36 age group shows 80%, 37-59 age groups demonstrates 75% and at least 60 years shows 48% cure rate. Therefore, demonstrating the requirement for government's emphasis on this fragment of society to keep away from loss of pay in future.

The Kaplan-Meier kink (Figure 6) reflects the difference in persistence opportunities, such as the possibility of a "cured" environmental health event between sexual orientation and treatment arm classification. The difference in endurance knots between the two sexual orientations is critical ($p = 0.091$; log-rank test), indicating that men have higher endurance at this point (more aversion needs to be restored). The difference in endurance entanglement between the two "treatment arms" is negligible ($p = 0.12$; log-rank test).

The empirical findings in Table 5 indicate the model results of the Cox proportional hazards model analysis. The gender hazard ratio (HR = 0.80) shows that men are 31% less likely to experience the environmental health outcomes of healing than women, and the sex category is negatively correlated with the duration of healing, as evidenced by the negative sign of the coefficient −0.31. Men are naturally more inclined to tuberculosis, and their personal behavior standards (such as smoking) will also affect the prevalence and outcome.

With the increase in medical use, the time to cure will decrease, 11% will almost certainly be cured, and the patient will recover (HR = 2.09; $p < 0.001$; coefficient = 0.11). In our investigation, according to the recommendations of clinical experts, better preventive measures are used to control the spread of infection in the climate. Convenient treatment results and hospitalization depend on the recommendations of clinical experts, which can shorten the recovery time.

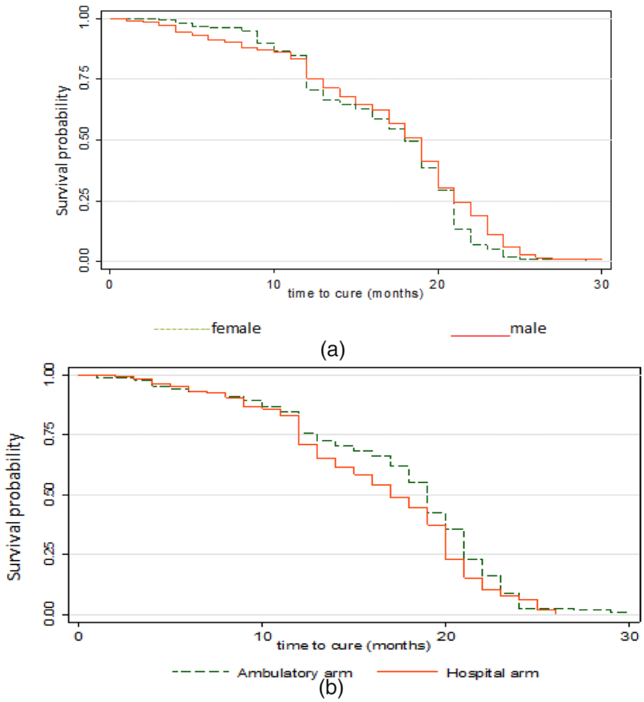

Figure 6. Kaplan -Meier survival curves for the categorical variables.

Table 5. Results of Cox proportional hazard model.

Covariate	Parameter estimate	HR	C.I (95%)
"Gender"	−0.31	0.80	0.621 to 0.992
"Medical expenditure"	0.11	2.09	2.055 to 2.128
"Travel expenditure"	−0.13	0.98	0.953 to 1.011
"Time expenditure'	0.05	1.12	1.012 to 1.029

"C.I shows value at 95% confidence interval and HR shows hazard ratio'

Travel expenses also have a negative effect on the duration of the cure for environmental-health outcomes (HR = 0.98). Patients are 13 percent less likely to be healed for every additional dollar spent on travel. All the more exorbitant methods for transportation additionally support recommendation of WHO[20] in regards to the plan of medication in ambulatory arm to diminish monetary weight on patients.

6. Conclusion

The investigation expects to analyze and identify the socio-economic, demographic, health policy and spatial attributes that have relationship with environmental-health effect of MDR-TB patients in China by utilizing the information of the MDR-TB sufferer's treatment regimens for the period of 2010–2019. The countries bearing the burden of this disease are striving hard to improve the treatment outcomes. Although, numerous studies have been presented for China related to the TB and MDR-TB treatment outcomes but the gap exist on literature related to the identification of the spatial and health policy related factors that can have potential association with the treatment outcome. Hence this study contributes in providing the evidence on the association of demographic, socio-economic, spatial, and health policy-related factors with the cure rate of MDR-TB patients.

Our study analysis demonstrates that the environmental-health result of cure has no major relationship with family income or age. The study level has insignificant association with cure, suggesting that health programs are effective in providing patients with adequate knowledge, and it supports the End TB Strategy[21] to enhance health awareness for better results.

From our research, we can deduce some relevant policy consequences. Since the greater parts of patients (98.6%) are between the ages of 15 and 56, the government should concentrate on developing sound environmental-health and socioeconomic policies to boost living conditions and reduce the loss of yield of this potentially lucrative community.

Declaration of conflicting interests

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Note

1. The standard definitions are extracted from World Health organization (2010).

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Appendix 1

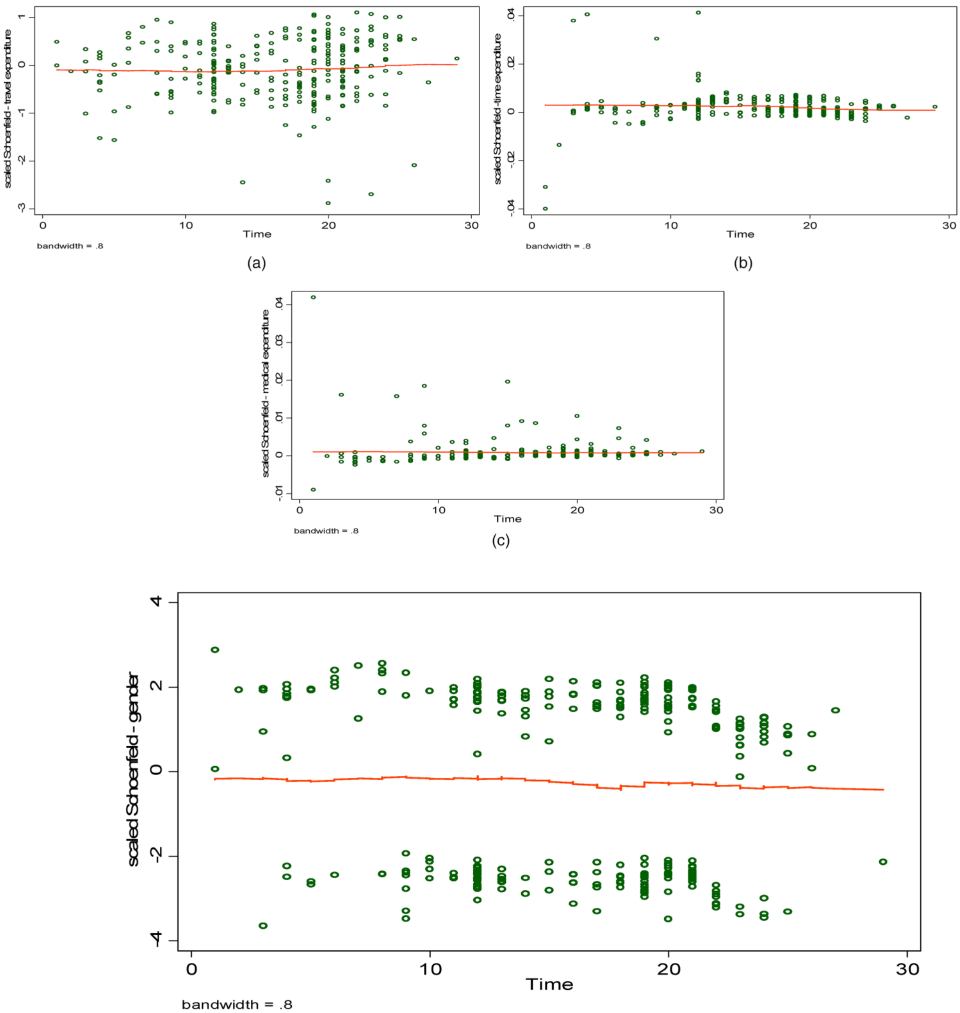

Figure A1. Scaled schoenfeld residuals and their LOESS smooth curve.