

# SCIENTIFIC REPORTS



OPEN

## Effect of China's maternal health policy on improving rural hospital delivery: Evidence from two cross-sectional surveys

Xiaojing Fan<sup>1,2</sup>, Yongjian Xu<sup>3</sup>, Martyn Stewart<sup>4</sup>, Zhongliang Zhou<sup>3</sup>, Shaonong Dang<sup>1</sup>, Duolao Wang<sup>2</sup> & Jianmin Gao<sup>3</sup>

This population-based cross-sectional study aims to explore the effect of China's Rural Hospital Delivery Subsidy (RHDS) policy on the utilization of women's hospital delivery between rural and urban areas. A total of 2398 women were drawn from the Fourth and Fifth National Health Service Surveys, from the Shaanxi province. A generalized linear mixed model was used to analyze the influence of the RHDS policy on the hospital delivery rate. Concentration index and decomposition methods were used to explore the equity of hospital delivery utilization. Prior to introduction of the RHDS policy, the difference in hospital delivery rates was  $-0.09$  (95% CL:  $-0.16, -0.01$ ) between rural and urban women when adjusting the influence of socioeconomic factors on hospital delivery; after implementation of the policy, the difference was reduced to  $0.02$  (95% CL:  $-0.01, 0.06$ ). The horizontal inequity index was reduced from  $0.084$  to  $0.009$  for rural women and from  $0.070$  to  $0.011$  for urban women. China's Rural Hospital Delivery Subsidy policy had some positive effect on reducing the gap between rural and urban women's hospital delivery rate and inequity. However, there is still a pro-rich inequity of hospital delivery utilization for both rural and urban women.

Maternal mortality rate (MMR) is an important indicator to evaluate the health status in developing countries<sup>1</sup>. The World Health Organization (WHO) defines maternal death as "the death of a woman during pregnancy or within a period of 42 days after the end of the pregnancy, regardless of the pregnancy duration or location, from any cause related to or aggravated by pregnancy or by measures related to it, but not from accidental or incidental causes"<sup>2</sup>. Every day, approximately 830 women die from preventable causes related to pregnancy and childbirth, 99% of which occur in developing countries<sup>3</sup>. In Brazil, MMR is 68 deaths per 100,000 livebirths<sup>4</sup>; in Bangladesh, MMR is 194 deaths per 100,000 livebirths<sup>5</sup>; in Ghana, it is 1004 per 100,000 livebirths<sup>6</sup>; in southern Nigeria, it is 1908 per 100,000 livebirths<sup>1</sup>. In China, the MMR was 27 per 100,000 livebirths<sup>7</sup>, lower than Brazil, Bangladesh, Ghana and southern Nigeria, but still higher than developed countries (12 per 100,000 livebirths)<sup>8</sup>. Hospital delivery, where pregnant women give birth to babies in hospital, is promoted as an effective strategy to prevent maternal and perinatal mortality since it is recognized that most obstetric complications occur at the time of delivery and cannot be predicted<sup>9</sup>.

The Chinese government has made many efforts to improve hospital delivery rates since 1995, such as the "Safe motherhood" and "Reducing maternal mortality and eliminating newborn tetanus" policies<sup>10,11</sup>. In 2003, three basic medical insurance schemes called "Urban Employee Basic Medical Insurance scheme", "New Rural Cooperative Medical Scheme" and "Urban Resident Basic Medical Insurance scheme" were introduced and can cover women's hospital delivery costs partially<sup>12</sup>. China's latest health system reform was initiated in April 2009 and one of its aims was to ensure the safety of maternal women. As part of this, a key policy, the Rural Hospital Delivery Subsidy (RHDS) policy for rural women was introduced in September 2009 to narrow the difference between maternal mortality rates existing between urban and rural areas. The RHDS policy is to reimburse

<sup>1</sup>Department of Epidemiology and Health Statistics, School of Public Health, Xi'an Jiaotong University Health Science Centre, Xi'an, P. R. China. <sup>2</sup>Department of Clinical Sciences, Liverpool School of Tropical Medicine, Liverpool, UK. <sup>3</sup>School of Public Policy and Administration, Xi'an Jiaotong University, Xi'an, P. R. China. <sup>4</sup>Department of Education and Training, Liverpool School of Tropical Medicine, Liverpool, UK. Correspondence and requests for materials should be addressed to D.W. (email: [duolao.wang@lstm.ac.uk](mailto:duolao.wang@lstm.ac.uk)) or J.G. (email: [gaojm@xjtu.edu.cn](mailto:gaojm@xjtu.edu.cn))

hospital delivery fees for rural women, aiming to achieve more than a 95% hospital delivery rate<sup>13</sup>. It provides 500 Ren Min Bi for each rural woman delivering at hospital and it is combined with New Rural Cooperative Medical Scheme to ease the financial burden of rural hospital delivery<sup>14</sup>.

Up to now, there have been some published studies supporting the role of the RHDS policy in influencing hospital delivery. Yang *et al.* found the RHDS policy promoted the hospital delivery services and reduced the regional difference<sup>14</sup>; Shen *et al.* observed the rate of hospital delivery increased after implementation of the RHDS policy in western China<sup>15</sup>; as did the studies of Song *et al.*<sup>16</sup> and Zhang *et al.* in Sichuan Province<sup>17</sup>. However, these study data are based on annual reports or local surveys at the level of the county. Whilst county-level reports are valuable, the relationship between RHDS policy and hospital delivery can only be fully understood at the individual level. The data through face-to-face interview can obtain the first-hand information directly, investigators can observe the respondent's response in a timely manner to get a more complete and accurate information<sup>18</sup>. However, there is no data available collected through face-to-face interviews to explore the relationship between RHDS policy and hospital delivery. Shaanxi Province, in the west of China, is an appropriate study area because of its predominantly rural character and high proportion of poor in the population, the type of area where the policy is needed most. Determining whether this policy has a positive effect on hospital delivery is important local health government strategies to promote the safe and health of maternal and newborns. Equity in healthcare has been a long-term guiding principle of health policy, and inequity remains a major challenge for health care planners and policy makers all over the world. In this study, two representative surveys based on face-to-face interviews are used firstly to explore whether the RHDS policy has made some influence on improving the hospital delivery rate in Shaanxi Province and the specific magnitude of inequity on hospital delivery utilization changes. Finally, we draw preliminary conclusions about whether the Chinese maternal health policies are progressing in the right direction.

## Results

**Changes of hospital delivery rate.** Table 1 presents the basic characteristics between urban women and rural women before and after the introduction of the RHDS policy. Before the policy, the difference in proportion between rural women who had a hospital delivery was 18.57% points (95% CL: 10.75%, 26.40%) lower than that of urban women [46.00% (95% CL: 41.32%, 50.67%) vs. 64.57% (95%CL: 58.30%, 70.85%);  $\chi^2 = 20.43$ ,  $P < 0.001$ ]. After the policy, the difference in rate was reduced to 1.47% (95% CL: 0, 3.98%) between rural and urban women [91.63% (95% CL: 89.94%, 93.33%) vs 93.10% (95%CL: 91.23%, 94.96%);  $\chi^2 = 1.26$ ,  $P = 0.262$ ]. Table 2 shows the results of the differences of Rural Hospital Delivery Subsidy policy on hospital delivery rate before and after RHDS policy by two GLMMs. When adjusting for the influence of women's age, health score, prenatal visits, chronic disease, health insurance, annual personal expenditure, parity, education and work status on hospital delivery rate in model 2, the difference in hospital delivery rates was  $-0.09$  (95%CL:  $-0.16$ ,  $-0.01$ ) between rural and urban women before the policy. After the policy, there was no difference in hospital delivery rates between them (mean difference: 0.02; 95%CL:  $-0.01$ , 0.06). This suggests the intervention of RHDS policy had some influence on reducing the gap in hospital delivery rate between rural and urban women.

**Equity of hospital delivery utilization.** Figure 1 shows that before the RHDS policy, concentration curves both in rural and urban women lay below the line of equality significantly, indicating that hospital delivery was more concentrated among the rich. However, the concentration curves were closer to the line of equality after the policy and the difference in concentration index between urban and rural women was reduced from 0.012 to  $-0.001$  (Table 3). In addition, the concentration index of occurring hospital delivery in rural women decreased significantly ( $P = 0.020$ ) from 0.082 (95% CL: 0.038, 0.156) to 0.009 (95% CL:  $-0.001$ , 0.022). This decreasing trend remains for urban women ( $P = 0.003$ ): 0.070 (95% CL: 0.020, 0.172) before the policy, and after 0.010 (95% CL:  $-0.002$ , 0.024, Table 3). Therefore, the differences in inequality of hospital delivery were reduced after the policy but still favoring the rich both in rural and urban women.

By decomposing the concentration index of the hospital delivery, the socioeconomic-related inequalities were decomposed into relative contributions of each determinant (see Supplementary Tables S1 and S2). Quantifying the corresponding contributions expressed as a percentage of each determinant before and after China's Rural Hospital Delivery Subsidy policy, most of the socioeconomic inequality in hospital delivery was attributable to annual personal expenditure, at 73.39 and 90.84 for rural women, 61.42 and 85.31 for urban women. Finally, it was computed that horizontal inequity indexes of occurring hospital delivery after the policy are 0.009 for rural women and 0.011 for urban women, evidencing a pro-rich inequity of hospital delivery utilization. In addition, the difference in horizontal inequity indexes of hospital delivery utilization between rural and urban women reduced from 0.014 (0.084 vs 0.070) before the policy to  $-0.002$  (0.009 vs 0.011) after the policy, indicating the inequity gap of hospital delivery utilization had been reduced after the policy (Table 4).

## Discussion

China bears some burden of global maternal mortality, the largest part being in the poor western provinces<sup>19</sup>. Hospital delivery should be completely covered because it has been recognized as an effective strategy in reducing maternal mortality. Although previous studies show women's higher socioeconomic characteristics (including age, education, work or not, parity and so on) may increase the hospital delivery rate, there is still a gap between urban and rural women<sup>20</sup>. In this study, we focused on China's Rural Hospital Delivery Subsidy policy and explored its influence on reducing the gap between rural and urban women's hospital delivery rate when adjusting for their socioeconomic characteristics. According to these two representative samples of health service surveys, the evidence supports the positive effect of the policy in reducing the difference in hospital delivery rate between rural and urban women. This finding is consistent with the evaluation of RHDS policy studies made by Song *et al.*, Zhang *et al.*, Shen *et al.* and Yang *et al.*<sup>14–17</sup>. It is the first study based on two representative surveys to

Variables	Before policy (n = 660)			After policy (n = 1738)		
	Urban	Rural	P	Urban	Rural	P
Hospital delivery						
No	79 (35.43)	236 (54.00)	<0.001	49 (6.9)	86 (8.37)	0.262
Yes	144 (64.57)	201 (46.00)		661 (93.10)	942 (91.63)	
Age (years)						
≤25	57 (25.56)	147 (33.64)	<0.001	195 (27.46)	350 (34.05)	<0.001
26–30	107 (47.98)	137 (31.35)		302 (42.54)	332 (32.30)	
≥31	59 (26.46)	153 (35.01)		213 (30.00)	346 (33.65)	
Health score	85.30 ± 8.59	85.41 ± 10.47	0.886	88.03 ± 8.25	86.98 ± 8.31	0.009
Chronic disease						
No	215 (96.41)	426 (97.48)	0.437	683 (96.20)	989 (96.21)	0.992
Yes	8 (3.59)	11 (2.52)		27 (3.80)	39 (3.79)	
Annual personal expenditure (Chinese Yuan)						
Poorest	54 (24.32)	249 (57.24)	<0.001	38 (5.35)	143 (13.91)	<0.001
Poorer	56 (25.23)	112 (25.75)		85 (11.97)	224 (21.79)	
Middle	55 (24.77)	48 (11.03)		130 (18.31)	245 (23.83)	
Richer	40 (18.02)	17 (3.91)		169 (23.80)	251 (24.42)	
Richest	17 (7.66)	9 (2.07)		288 (40.56)	165 (16.05)	
Parity						
1	193 (86.94)	258 (59.58)	<0.001	432 (60.93)	496 (48.39)	<0.001
≥2	29 (13.06)	175 (40.42)		277 (39.07)	529 (51.61)	
Prenatal visits	7.67 ± 4.16	5.06 ± 2.70	<0.001	6.36 ± 3.39	5.71 ± 2.56	<0.001
Education						
≤Primary school	8 (3.59)	133 (30.57)	<0.001	78 (11.02)	232 (22.59)	<0.001
Middle school	84 (37.67)	245 (56.32)		371 (52.40)	620 (60.37)	
≥High school	131 (58.74)	57 (13.10)		259 (36.58)	175 (17.04)	
Employment						
No	99 (44.39)	65 (14.87)	<0.001	220 (30.99)	156 (15.18)	<0.001
Yes	124 (55.61)	372 (85.13)		490 (69.01)	872 (84.82)	
Health insurance						
No	45 (20.18)	11 (2.52)	<0.001	87 (12.25)	27 (2.63)	<0.001
Yes	178 (79.82)	426 (97.48)		623 (87.75)	1001 (97.37)	

**Table 1.** Descriptions of characteristics among participants before and after China's Rural Hospital Delivery Subsidy [ $\bar{x} \pm sd/n$  (%)].  $\bar{x}$ : mean;  $sd$ : Standard Deviation.

Comparison	Model 1				Model 2			
	Mean difference	95% Confidence Limits		P	Mean difference	95% Confidence Limits		P
		Lower	Upper			Lower	Upper	
Before policy								
Rural vs Urban	−0.15	−0.22	−0.07	<0.001	−0.09	−0.16	−0.01	0.028
After policy								
Rural vs Urban	−0.02	−0.05	0.02	0.343	0.02	−0.01	0.06	0.230

**Table 2.** Rural-urban difference in hospital delivery before and after China's Rural Hospital Delivery Subsidy policy (n = 2398). Generalized linear mixed model was used to estimate the interaction effect between China's Rural Hospital Delivery Subsidy policy and site on hospital delivery rate. In model 1, policy, site and policy\*site are treated as fixed effects and village as random effect. The model 2 is the model 1 plus women's age, health score, prenatal visits during pregnancy, chronic disease, health insurance, annual household income, parity, education and work.

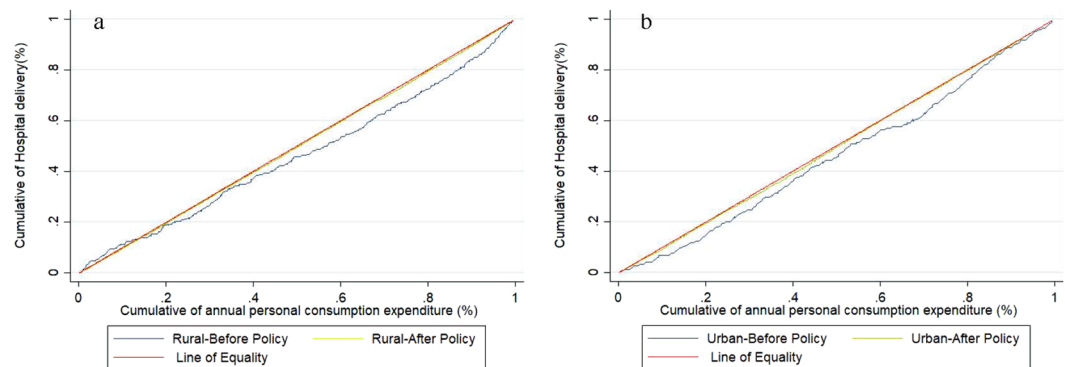
explore the relationship between RHDS policy and hospital delivery in Shaanxi Province. A positive direction of the RHDS policy in improving the safe and health of maternal and newborns has been concluded and provides a strong evidence base to inform health policy. Now, the hospital delivery rate for rural women is at a similar level to that of urban women (91.63% vs 93.10%) in Shaanxi Province. Besides, the hospital delivery rate for rural women in Shaanxi was 91.63% in 2013 which, whilst still higher than the rate of 86.3% reported by Liu *et al.* in 2011<sup>21</sup>, is still lower than the rates in Zhejiang (99.98%)<sup>22</sup> and other regions (97.8%) in China<sup>16</sup>. It is higher than for many developing countries though. In Pakistan, the rate of hospital delivery was 40% for rural areas<sup>23</sup> in

Variable	Before policy			After policy		
	CI <sup>1</sup>	95% Confidence Limits		CI <sup>1</sup>	95% Confidence Limits	
Rural	0.082	0.038	0.156	0.009	−0.001	0.022
Urban	0.070	0.020	0.172	0.010	−0.002	0.024
Difference	0.012	—	—	−0.001	—	—

**Table 3.** Inequality of urban and rural women's hospital delivery before and after China's Rural Hospital Delivery Subsidy policy (n = 2398). <sup>1</sup>CI: Concentration Index.

Groups	Rural				Urban			
	Before policy		After policy		Before policy		After policy	
	Contribution to CI <sup>1</sup>	% <sup>2</sup>	Contribution to CI <sup>1</sup>	% <sup>2</sup>	Contribution to CI <sup>1</sup>	% <sup>2</sup>	Contribution to CI <sup>1</sup>	% <sup>2</sup>
CI <sup>1</sup>								
	0.082	100	0.009	100	0.070	100	0.010	100
Contributions of factors to CI <sup>1</sup>								
Needs variables <sup>3</sup>	−0.002	−2.19	0.000	−5.14	0.000	−1.47	−0.001	−5.08
Annual personal expenditure (Chinese Yuan)								
	0.060	73.39	0.008	90.84	0.043	61.42	0.008	85.31
Other variables <sup>4</sup>	0.010	12.08	0.004	31.13	0.004	5.06	0.001	10.14
Residual	0.014	16.72	−0.003	−16.83	0.230	34.99	0.002	9.63
Horizontal inequity index								
	0.084	—	0.009	—	0.070	—	0.011	—

**Table 4.** Contributions of factors and horizontal inequity of women's hospital delivery before and after China's Rural Hospital Delivery Subsidy policy (n = 2398). <sup>1</sup>Concentration Index. <sup>2</sup>Pure percentage contributions of determinants to the socioeconomic inequality in hospital delivery. <sup>3</sup>Including age, health score and chronic disease. <sup>4</sup>Including women's prenatal visits during pregnancy, health insurance, parity, education and work.



**Figure 1.** Concentration curves on hospital delivery before and after China's Rural Hospital Delivery Subsidy policy (a = Rural, b = Urban).

2012–2013, and among Indian rural women it was 69.7%, as reported through the Sample Registration System, Registrar General of India<sup>24</sup>. So, whilst the status of rural and urban hospital delivery rate in Shaanxi was not low, and it had increased in recent years.

China is a huge country with significant rural-urban differences, and rural areas are usually recognized as having a lower quality of health care<sup>25</sup>. The government conducted the health system reform and introduced a basic health insurance system in order to eliminate the rural-urban disparity in health care. These two policies helped redistribute health resources towards rural areas. However, substantial rural-urban inequality in delivery still exists with more hospital deliveries in urban than in rural areas<sup>26,27</sup>. One of the encouraging findings in this study is that the difference in rural hospital delivery inequality was also reduced after the introduction of the RHDS policy, demonstrating that implementation of maternal policies since 2009 has led the rural health service utilization development in a positive direction<sup>28</sup>. However, the concentration indexes of hospital delivery utilization between rural and urban were positive, showing that obvious pro-rich inequalities of hospital delivery utilization still remain, and indicating that a disproportionate share of hospital delivery resources is utilized by wealthier people despite lower need. These results are consistent with findings of many other studies in different parts of

the world<sup>26,29,30</sup>. Therefore, the focus of public health policy still needs to remain on the expansion of the maternal health utilization with an emphasis among poor women.

The study has a few limitations. First, this is an observational study and the determinants of hospital delivery included in this study are limited by the pre-specified questions in the surveys. There could be some potential unobserved confounding factors we did not control for. Second, the imbalanced data before (660) and after (1738) the policy may have two potential impacts on the results and conclusions. One potential impact is the smaller data before the policy are less representative of the study population than that of the larger one after the policy, introducing possible more selection bias into the statistical results related to the data before the policy; another potential impact is the imbalanced data may generate results with less statistical efficiency (eg, larger standard error and less statistical significance) compared with the balanced one. Last but not the least, all the data were collected by a self-report approach, and there may be recall bias. However, it is suggested that, as pregnancy and childbirth are prominent life events, the associated heightened attention is likely to reduce effects of recall bias.

In summary, the evidence supports the positive effect of China's Rural Hospital Delivery Subsidy policy in reducing the gap in hospital delivery rate and inequity between rural and urban women. However, there is still a pro-rich inequity of hospital delivery utilization for both rural and urban women and efforts should still be made to increase utilization of maternal health services in order to realize the full coverage of hospital delivery and eliminate the rural-urban inequity in health care.

## Methods

**Study setting and data source.** Data were drawn from the 4<sup>th</sup> (in 2008) and 5<sup>th</sup> (in 2013) National Health Service Surveys (NHSS) conducted in Shaanxi Province before and after the introduction in 2009 of China's Rural Hospital Delivery Subsidy (RHDS) policy. The NHSS is a national representative survey conducted by the National Health and Family Planning Commission of China every five years<sup>31</sup>. Considering the hierarchical structure of Chinese administrative districts and the imbalanced population distributions among the different provinces, a multistage stratified sampling method was used to ensure the samples were representative of the whole population of each province. The structured strategy for sampling in Shaanxi in the 4<sup>th</sup> and 5<sup>th</sup> NHSS was introduced by Zhou *et al.* and Yang *et al.*<sup>32,33</sup>.

During the survey, all household members were interviewed face to face individually using a structured household questionnaire (see Supplementary Questionnaire S1 and S2). A total of 18,290 household members in the 4<sup>th</sup> NHSS and 57,529 household members in the 5<sup>th</sup> NHSS were collected. For our study, only women who had at least one delivery were selected as the sampling unit of interest in the 4<sup>th</sup> NHSS. From the 5<sup>th</sup> NHSS, only women whose last delivery occurred after January 2010 were selected considering the publishing time of RHDS policy (September 2009) and the consistencies in implementation among hospitals and related departments (for example, the health insurance department). Finally, data from 660 women in the 4<sup>th</sup> NHSS and 1,738 women in the 5<sup>th</sup> NHSS were utilized for this analysis. Given the hospital delivery rate (88.8%) in rural area of China before the 4<sup>th</sup> National Health Services Survey<sup>34</sup>, the sample size was calculated as 510 with a permissible error of 3%, a type I error of 0.05 and an expected 20% non-response rate. Thus, the number of the women from these two cross-sectional studies met the requirement of hospital delivery analysis.

**Ethics.** This study protocol was approved by the Ethics Committee of Xi'an Jiaotong University Health Science Center (the 4<sup>th</sup> NHSS Approval No. 2014–204 and the 5<sup>th</sup> NHSS Approval No. 2015-644). In addition, the study was in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Verbal informed consent was obtained by NHSS surveyors from each participant before the original survey.

**Main outcome and predictor variables.** In the household questionnaire of the 4<sup>th</sup> and 5<sup>th</sup> NHSS, women were asked to describe the type of delivery institution from six category options: county hospital and above, maternal and child health care institution, township health center, community health center, village clinic and at home. According to China's status for medical institutions after December 2009, we divided them into two groups:  $\geq$ secondary institution (including county hospital and above, maternal and child health care institution) and  $\leq$ primary institution (including township health center, community health center, village clinic and at home). Women who had a delivery at  $\geq$ secondary institution were identified as having hospital delivery. The settings characterized as primary institutions were considered to lack sufficient equipment, doctors and, or nurses to ensure a safe delivery. The indicator used to measure the effect of the Rural Hospital Delivery Subsidy policy for rural maternal women was the occurrence of hospital delivery (a binary outcome variable). According to the RHDS policy that only rural women could receive a subsidy after a hospital delivery, rural women were selected to be the intervention group. The policy had not yet been implemented among urban women from the 4<sup>th</sup> NHSS to the 5<sup>th</sup> NHSS, making the urban women to be an excellent control for this study. It is hypothesized that the occurrence of hospital delivery in rural areas would be increased after implementing the RHDS.

**Statistical analysis.** Generalized linear mixed models (GLMM) are an extension of generalized linear models and include both fixed and random effects<sup>35</sup>. The response variable can come from different distributions. In this study, GLMM was employed to analyze the effect of the RHDS policy on hospital delivery after controlling a number of confounding factors. These variables were selected based on previous studies but constrained by the variables collected in the survey<sup>16,36,37</sup>. The characteristics of the whole variables used are shown in Table 1. The variables policy, site, and interaction between policy and site were specified as fixed effects, and the village where women lived as a random effect. Health insurance, health score, annual personal expenditure, parity, chronic disease, prenatal visits, age, education, work were covariates. In a GLMM, the linear prediction  $\eta$  is the combination of the fixed and random effects excluding the residuals.



$$\begin{aligned}\eta &= X\beta + Z\gamma \\ g(\cdot) &= \text{link function} \\ h(\cdot) &= g_{-1}(\cdot) = \text{inverse link function}\end{aligned}\quad (1)$$

$g(\cdot)$  is the link function which relates the outcome  $y$  to the linear predictor  $\eta$ . The equation is as follow:

$$g(E(Y)) = X\beta + Z\gamma \quad (2)$$

Here, we use the multiple generalized linear mixed model:

$$\eta(y_{ij}) = \beta_{0j} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + \beta_{3j}x_{1i}x_{2i}\cdots + \beta_{pj}x_{pi} + \varepsilon_{ij} \quad (3)$$

In equation (3),  $y_{ij}$  is the hospital delivery takes the value of 0 and 1.  $\beta_{0j}$  is a constant,  $\beta_{pj}$  represent the effects of  $x_{pi}$  on  $y$ , and  $\varepsilon_{ij}$  is a random error. The link function is identity. In this study, interaction effect may exist between RHDS policy and site (urban, rural) when  $\beta_{3j} \neq 0$ <sup>38</sup>.

**Methods to measure hospital delivery inequality.** Concentration index (CI) was employed to measure the extent of income-related inequality of healthcare utilization<sup>39</sup>. It is defined as twice the area between the concentration curve and the line of equality and ranges from  $-1$  to  $+1$ <sup>40</sup>. The formula for computing the concentration index is as follows:

$$C = \frac{2}{\mu} \text{cov}_w(Y_i, R_i) \quad (4)$$

where  $C$  stands for concentration index,  $y_i$  is the hospital delivery status of the  $i$ th individual, and  $R_i$  is the fractional rank of the  $i$ th individual (for weighted data) in terms of the index of annual personal economic status.  $\mu$  is the (weighted) mean of hospital delivery index and  $\text{cov}_w$  denotes the weighted covariance. If  $C$  is positive, it means high-income people utilize more hospital delivery than their low-income counterparts. Meanwhile, the  $C$  is negative if the low-income group utilizes more hospital delivery than their rich counterparts. When all hospital delivery resources are utilized by low-income group the concentration index will be  $-1$  and it will be  $+1$  when the high-income group are favored in hospital delivery utilization. Hospital delivery is equitably utilized by the poor and the rich when the index is 0<sup>41</sup>.

**Horizontal inequity of hospital delivery.** Horizontal inequity index (HI) is a summary measure of the magnitude of inequity in the dependent variable, used to measure whether the extent of deviation in the use of healthcare for people is equal for healthcare irrespective of their income<sup>42,43</sup>. HI is computed by subtracting the contribution of need variables (such as age, health score and having chronic disease or not) from the concentration index of hospital delivery, which is used to measure the equity of hospital delivery. Decomposition methods enable researchers to quantify each determinant's true contribution to measured income-related inequality with the controlling of other determinants<sup>44</sup>. Since the outcome variable, hospital delivery, was binary with the range of (0, 1), Probit regression model was used to indirectly standardize the healthcare service utilization. As the standardization of health utilization holds for a linear model of healthcare, we applied the linear approximation to the Probit model to extract marginal effects of each determinant on observed probabilities of the outcome variable. The formula can be written as follows<sup>39,45</sup>:

$$y_i = G\left(\alpha + \sum_j \beta_j x_{ji} + \sum_k \gamma_k z_{ki}\right) + \varepsilon_i \quad (5)$$

$G$  is functional transformation,  $y$  is the dependent variable,  $x_{ji}$  are needs variables, and  $z_{ki}$  are control variables. Then the standardized need was estimated using the following equation:

$$\hat{y}_i^{IS} = y_i - G\left(\hat{\alpha} + \sum_j \hat{\beta}_j x_{ji} + \sum_k \hat{\gamma}_k z_{ki}\right) + \frac{1}{n} \times \sum_{i=1}^n G\left(\hat{\alpha} + \sum_j \hat{\beta}_j x_{ji} + \sum_k \hat{\gamma}_k z_{ki}\right) \quad (6)$$

where  $\hat{y}_i^{IS}$  is standardized hospital delivery utilization,  $n$  is sample size. The more hospital delivery allocated to the needed, the less inequity of hospital delivery utilization.

All questionnaires had been checked for missing data and outliers, then cleaned prior to data analysis. Continuous variables were summarized as means with standard deviations, and categorical variables as number and percentages. Differences in variables between rural and urban areas were compared by either  $t$  test or chi-squared test. The statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA) and STATA statistical software version 12.0 (StataCorp LP, College station 77845, USA). A two-tailed  $P$  value  $< 0.05$  was considered statistically significant.

**Availability of materials and data.** The datasets analyzed during the current study are not publicly available due to confidential data only be available from the Shaanxi Health and Family Planning Commission for researchers who meet the criteria but are available from the corresponding author on reasonable request. Researchers who want to use these data should contact Jianmin Gao (gaojm@mail.xjtu.edu.cn).

## References

- Mbachu, I. I. *et al.* A cross sectional study of maternal near miss and mortality at a rural tertiary centre in southern nigeria. *BMC Pregnancy and Childbirth* **17**, 251, <https://doi.org/10.1186/s12884-12017-11436-z>. (2017).
- Alkema, L. *et al.* Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. *Lancet* **387**, 462–474 (2016).
- Tuncalp, O., Hindin, M. J., Adu-Bonsaffoh, K. & Adanu, R. M. Assessment of maternal near-miss and quality of care in a hospital-based study in Accra, Ghana. *Int J Gynaecol Obstet* **123**, <https://doi.org/10.1016/j.ijgo.2013.06.003> (2013).
- Moreira, D. D. S. & Gubert, M. B. Healthcare and sociodemographic conditions related to severe maternal morbidity in a state representative population, Federal District, Brazil: A cross-sectional study. *PLOS ONE* **12**, e0180849, doi:10.0181371/journal.pone.0180849, eCollection0182017 (2017).
- Arifeen, S. E. *et al.* Maternal mortality in Bangladesh: a Countdown to 2015 country case study. *Lancet* **384**, 1366–1374 (2014).
- QY, L., At, O., H, O.-A. & ET, D. Maternal mortality in Ghana: a hospital-based review. *Acta Obstet Gynecol Scand* **91**, 87–92 (2012).
- WHO. *Maternal and reproductive health*, [http://gamapsrver.who.int/gho/interactive\\_charts/mdg5\\_mm/atlas.html](http://gamapsrver.who.int/gho/interactive_charts/mdg5_mm/atlas.html) (2015).
- WHO, Unicef, Unfpa, World Bank Group & United Nations Population Division. *Trends in maternal mortality: 1990 to 2015. Estimates by WHO UNICEF UNFPA World Bank Group and the United Nations Population Division* (2015).
- Pardeshi, G. S., Dalvi, S. S., Pergulwar, C. R., Gite, R. N. & Wanje, S. D. Trends in Choosing Place of Delivery and Assistance during Delivery in Nanded District, Maharashtra, India. *Journal of Health Population & Nutrition* **29**, 71–76 (2011).
- United Nations Children's Fund. *Maternal and neonatal tetanus eliminated in China*, <http://www.unicef.cn/en/index.php?m=content&c=index&a=show&catid=53&id=3653> (2012).
- Liu, X., Yan, H. & Wang, D. The evaluation of "Safe Motherhood" program on maternal care utilization in rural western China: a difference in difference approach. *Bmc Public Health* **10**, 1–6 (2010).
- Gao, Y., Barclay, L., Kildea, S., Hao, M. & Belton, S. Barriers to increasing hospital birth rates in rural Shanxi Province, China. *Reprod Health Matters* **18**, 35–45 (2010).
- National Health and Family Planning Commission of the People's Republic of China. *Announcement on Rural Maternal Hospital Childbirth Subsidy Project by the Ministry of Health*, <http://www.moh.gov.cn/mohbgt/s9513/200909/42975.shtml> (2009).
- Yang, Z. & Wang, Z. Status Analysis of the Design and Implementation of Hospital Delivery Subsidy Policy of Rural Pregnant and Lying -in Women. *Chinese Health Economics* **32**, 64–67 (2013).
- Shen, J., Xie, Z., Jian, W. & Guo, Y. Evaluation of institutional delivery subsidy program in rural China. *Chinese Journal of Health Plicy* **5**, 54–59 (2012).
- Song, P. *et al.* Barriers to Hospital Deliveries among Ethnic Minority Women with Religious Beliefs in China: A Descriptive Study Using Interviews and Survey Data. *International Journal of Environmental Research and Public Health* **13**, 815, doi:D-NLM: PMC4997501 OTO-NOTNLM (2016).
- Zhang, Y. *et al.* Evaluation of institutional delivery subsidy program in rural Sichuan province. *Chinese Journal of Family Planning & Gynecotokology* **6**, 74–78 (2014).
- Yang, M. *Research on Questionnaire-based Data Collection and Analysis* Master thesis, Shandong Normal University (2011).
- Du, Q. *et al.* The trends in maternal mortality between 1996 and 2009 in Guizhou, China: ethnic differences and associated factors. *Journal of Huazhong University of Science and Technology [Medical Sciences]* **35**, 140–146 (2015).
- Gabrysch, S. & Campbell, O. M. Still too far to walk: Literature review of the determinants of delivery service use. *Bmc Pregnancy & Childbirth* **9**, 34 (2009).
- Liu, X., Zhou, X., Yan, H. & Wang, D. Use of maternal healthcare services in 10 provinces of rural western China. *Int J Gynaecol Obstet* **114**, 260–264 (2011).
- Zhang, W. F., Xu, Y. H., Yang, R. L. & Zhao, Z. Y. Indicators of child health, service utilization and mortality in Zhejiang Province of China, 1998–2011. *PLOS ONE* **8**, e62854, <https://doi.org/10.61371/journal.pone.0062854> (2013).
- Parveen, Z., Sadiq, M., Abbas, F. & Amir-ud-Din, R. Correlates of home and hospital delivery in Pakistan. *J Pak Med Assoc* **67**, 1166–1172 (2017).
- Singh, S. K., Kaur, R., Prabhakar, P., Gupta, M. & Kumar, R. Improving Perinatal Health: Are Indian Health Policies Progressing In The Right Direction? *Indian Journal of Community Medicine Official Publication of Indian Association of Preventive & Social Medicine* **42**, 116–119 (2017).
- Meng, Q., Zhang, J., Yan, F., Hoekstra, E. J. & Zhuo, J. One country, two worlds - the health disparity in China. *Glob Public Health* **7**, 124–136 (2012).
- Liu, X., Gao, W. & Yan, H. Measuring and decomposing the inequality of maternal health services utilization in western rural China. *BMC Health Serv Res* **14**, 102 (2014).
- Phiri, S. Na, Fylkesnes, K., Moland, K. M., Byskov, J. & Kiserud, T. Rural-Urban Inequity in Unmet Obstetric Needs and Functionality of Emergency Obstetric Care Services in a Zambian District. *PLOS ONE* **11**, e0145196, <https://doi.org/10.1371/journal.pone.0145196> (2016).
- Tian, M. *et al.* China's rural public health system performance: a cross-sectional study. *PLOS ONE* **8**, e83822, <https://doi.org/10.1371/journal.pone.0083822> (2013).
- Mehata, S. *et al.* Trends and Inequalities in Use of Maternal Health Care Services in Nepal: Strategy in the Search for Improvements. *Biomed Res Int* **2017**, <https://doi.org/10.1155/2017/5079234>. (2017).
- Haider, M. R. *et al.* Impact of maternal and neonatal health initiatives on inequity in maternal health care utilization in Bangladesh. *PLOS ONE* **12**, e0181408, doi:10.0181371/journal.pone.0181408 (2017).
- Gao, J., Tang, S., Tolhurst, R. & Rao, K. Changing access to health services in urban China: implications for equity. *Health Policy Plan* **16**, 302–312 (2001).
- Zhou, Z. *et al.* The effect of urban basic medical insurance on health service utilisation in Shaanxi Province, China: a comparison of two schemes. *Plos One* **9**, e94909, <https://doi.org/10.1371/journal.pone.0094909> (2014).
- Yang, X. *et al.* Assessing the Effects of the New Cooperative Medical Scheme on Alleviating the Health Payment-Induced Poverty in Shaanxi Province, China. *Plos One* **11**, e0157918, <https://doi.org/10.1371/journal.pone.0157918> (2016).
- Zhang, Y. *et al.* Secular trends of institutional delivery rate in China from 1996 to 2015. *Zhonghua yi xue za zhi* **97**, 1337–1342 (2017).
- Wang, D. In *Interaction. Clinical Trials: A Practical Guide to Design, Analysis and Reporting* (ed. A Bakhai) 496pp (ReMEDICA, 2006).
- Friedman, A. M., Ananth, C. V., Huang, Y., D'Alton, M. E. & Wright, J. D. Hospital delivery volume, severe obstetrical morbidity, and failure to rescue. *American Journal of Obstetrics and Gynecology* **215**, 795.e791–795.e714, <https://doi.org/10.1016/j.ajog.2016.07.039> (2016).
- Seraphin, M. N. *et al.* Determinants of institutional delivery among women of childbearing age in rural Haiti. *Matern Child Health J* **19**, 1400–1407 (2015).
- Gen, Z. & Hu, Y. Statistical inference of interaction. *Zhong Hua Liu Xing Bing Xue Za Zhi* **23**, 221–224 (2002).
- Zhou, Z. *et al.* Assessing equity of healthcare utilization in rural China: results from nationally representative surveys from 1993 to 2008. *International Journal for Equity in Health* **12**, 34 (2013).
- Wagstaff, A. The bounds of the concentration index when the variable of interest is binary, with an application to immunization inequality. *Health Economics* **14**, 429–432 (2005).

41. Pathak, P. K., Singh, A. & Subramanian, S. V. Economic Inequalities in Maternal Health Care: Prenatal Care and Skilled Birth Attendance in India, 1992–2006. *PLOS ONE* 5, e13593 (2010).
42. Almeida, G. & Sarti, F. M. Measuring income related inequality in health: standardisation and the partial concentration index. *Revista Panamericana De Salud Pública* 33, 83–89 (2013).
43. Wagstaff, A. & Doorslaer, E. V. Measuring and Testing for Inequity in the Delivery of Health Care. *Journal of Human Resources* 35, 716–733 (2000).
44. Wagstaff, A., Van, D. E. & Watanabe, N. On decomposing the causes of health sector inequalities with an application to malnutrition inequalities in Vietnam. *Washington D* 112, 207–223 (2001).
45. Kien, V. D., Van Minh, H., Giang, K. B., Weinehall, L. & Ng, N. Horizontal inequity in public health care service utilization for non-communicable diseases in urban Vietnam. *Global Health Action* 7, 24919, <https://doi.org/10.3402/gha.v7.24919> (2014).

### Acknowledgements

This study was funded by the Project of Shaanxi Social Science Foundation (2017S024), Research Program of Shaanxi Soft Science (2015KRM117), Shaanxi provincial youth star of science and technology and China Medical Board (15–227). We express our appreciation to all participants in this study for their participation and co-operation, to the leaders and staffs of Shaanxi Health and Family Planning Commission, to the guiders from the sample counties for their co-operation and organization in the data collection.

### Author Contributions

Conceived and designed the study: X.F., Y.X. and Z.Z. Collected the data: J.G. and Z.Z. Conducted the data analysis and prepared the manuscript: X.F., W.D., M.S. and S.D. All authors critically reviewed and approved the final manuscript.

### Additional Information

**Supplementary information** accompanies this paper at <https://doi.org/10.1038/s41598-018-29830-8>.

**Competing Interests:** The authors declare no competing interests.

**Publisher's note:** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2018