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Rural centralized residences and the health of the acting heads of rural households: The case of China

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ABSTRACT

The rural centralized residence (RCenR) has been adopting to promote rural development in 24 provinces in China. Acting heads of rural households are older and their health is worse than average rural residents. However, their health has greater externalities since they play a central role in families and in daily village operations. It is therefore important to investigate the causal effect of RCenR on the health of the acting heads, which remains econometrically underexplored. This study controls for cross-prefecture contiguous-villages group fixed effects and uses the expected once-off government housing subsidy as the instrumental variable to estimate the causal effect of RCenR on the health of acting heads. It is found that RCenR significantly improves acting heads' health through increased income, reduced strenuous agricultural activities, greater use of clean energy and clean water, as well as easier access to local medical services. These findings are important because they can guide developing countries to improve their rural development policies.

1. Introduction

Health plays an integral role in the quality of life, and is central to human survival and development (United Nations Development Programme, 1990). Health is also essential for human capital, which significantly contributes to economic growth, especially in rural areas of developing countries (Barro, 1996; Bloom & Canning, 2003). Good health may generate higher income by increasing the productivity and working hours of rural residents (García-Gómez, 2011; Pelkowski & Berger, 2004), whereas disease has a substantial negative impact on their welfare (Alam & Mahal, 2014; Garg, & Karan, & A. K., 2009). By reducing medical expenses, better health can prevent rural populations from falling into the "poverty trap." According to a 2022 World Health Organization (WHO) report, more than one third of the world's population lacks access to basic health care services, and about 13% encounters expensive health care, particularly in the rural areas of developing countries (WHO, 2022). In addition, rural residents have lower life expectancy and poorer health than their urban counterparts (Anyamele, 2009; Scheiladlung, 2015). This situation is primarily caused by a lack of health care resources (Hammer & Spears, 2016; WHO, 2010). Residents in rural areas also experience low medical insurance coverage and a

Abbreviations: IV, Instrumental Variable; LATE, Local Average Treatment Effect; OLS, Ordinary Least Squares; RCenR, Rural Centralized Residence; 2SLS, Two-stage Least Squares; WHO, World Health Organization; Sub_RCenR, Expected Once-off Government Housing Subsidy for RCenR; Cross-Pre-Vil-Group, Cross-Prefecture Contiguous-Villages Group; Cross-Pre-Vil-Group FE, Cross-Prefecture Contiguous-Villages Group Fixed Effects; UCI, Union of Confidence Interval; GMM, Generalized Method of Moments.

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deterioration of their living environment, which may undermine their physical and mental health, and therefore, their quality of life (Black, Sanders, Taylor, & Taylor, 2015; Lai, 2017).

Rapid urbanization and industrialization led to rural recessions in many developed countries and regions after World War II. This resulted in diminished rural populations, the abandonment of arable land, and a significant decrease in the quality of infrastructure (Bjørnå & Aarsæther, 2009; McGreevy, 2012). To address these issues, countries such as the United Kingdom (UK) and Japan developed rural centralized residences (RCenR), a rural development policy that concentrated dispersed rural households into central communities (Cloke, 1979; Lerise, 2000; Palmer, 1988).

China has been gradually implementing RCenR policies in rural areas since 2004 as well. RCenR was established to develop rural areas and organize rural residences in the face of rapid urbanization. RCenR can achieve more efficient land arrangement and save rural construction land. Centralized residences and saved land earmarked for construction can attract and create more businesses in rural areas as well as providing greater opportunities of local non-agricultural business and employment. Moreover, RCenR communities have more aggregated population and governments can build infrastructure and provide public services to rural areas at a lower cost, leading to a better balance of welfare distribution between urban and rural areas. Essentially, RCenR relocates dispersed rural residents to centralized communities, resulting in significant changes to their production modes, lifestyle, and social welfare. RCenR may also have an important impact on the health of rural residents. Although many countries have resorted to RCenR to address rural development problems, the impact of RCenR on the health of rural residents remains underexplored econometrically.

This study examines the effect of RCenR on the health of acting heads of rural households (shortened as 'acting heads' hereafter) in China. Rapid industrialization and urbanization have driven a large number of farmers to out-migrate to cities as workers (Xu, 2017; Zhao, 1999). The out-migration of young and middle-aged workforce has resulted in many household members being left behind in rural areas, notably older people, women, and children. Numerous studies have examined the resultant welfare changes in these groups (Antman, 2011; Böhme, Persian, & Stöhr, 2015; Jacka, 2012; Zhang, Behrman, Fan, Wei, & Zhang, 2014). However, the well-being of rural acting heads represents a gap in the literature. In this paper, the acting head refers to the de facto head of the household among the family members who remain in the local area. If there are no out-migrant workers in a family, or if the registered head of the family chooses not to out-emigrate, the acting head is then the registered. In this study, 58% of households have at least one out-migrant worker in their families.[1]

The acting heads play a central role in their family and in the community (Schatz, Madhavan, & Williams, 2011). They are the decision-makers in terms of financial and other important household affairs, and they are the core of daily family operations (Lei & Desai, 2021; Schatz et al., 2011; Yabiku, Agadjanian, & Sevoyan, 2010). Acting heads also have an important effect on the health of the family members (Fu, 2022) and the education of the younger generation (Yan, Peng, Hao, Irfan, & Wu, 2021). Fu (2022) notes that if the acting heads are healthy, the probability of incurring heavy medical expenses for the households can be reduced by 5.5%. In addition, acting heads are key participants in community or village affairs (Maharjan, Bauer, & Knerr, 2012; Tong, Chen, & Shu, 2019). Greater household decision-making power allows the acting heads to play a stronger role in their family and community. Thus, the health of acting heads has greater externalities. On the other hand, the acting heads are older and their health is worse than average rural residents. In the survey dataset collected in 2017 that this study uses, the mean of the ages of acting heads is 55.03 years old (standard deviation = 12.16), which is much larger than that of rural population (46.19 years old) including left-behind and non-left-behand calculated by using China Family Panel Studies dataset,[2] and they are in the range of ages with higher number of new cancer cases and cancer deaths of all cancers and five leading cancer types (Zheng et al., 2022). In the dataset this study uses, only 54.8% of the acting heads feel that they are healthy. The ratio is much lower than that of rural residents (65.10%).[3] Since acting heads are older and less healthy than average rural population and their health has greater externalities, it is very important to examine the effect of RCenR on the health of acting heads, which this study aims to do.

However, unobservable factors and possible reverse causality may make it difficult to estimate the causal effect of RCenR on the health of the acting heads. To overcome these concerns, this study adopts two strategies. First, it adopts an approach similar to Dube, Lester, and Reich (2010), who used contiguous cross-state county pairs in the USA. By controlling for contiguous cross-state county pairs fixed effects, Dube et al. (2010) attempted to address endogeneity derived from omitted factors, which are identical in a given contiguous cross-state county pair. In this paper, a similar strategy is adopted for controlling the cross-prefecture contiguous-villages group fixed effects (Cross-Pre-Vil-Group FE). The strategy aims to control for unmeasured or unobserved factors that are identical for the acting heads in the same group. Second, the study adopts the expected once-off government housing subsidy as an instrumental variable (IV) for *RCenR*, in line with Liu, Wang, Xiong, and Liu (2020). This study conducts multiple tests to verify the validity of the proposed IV.

Prior studies on changes in the living environment and their effect on farmers' health focused mainly on the impact of urbanization, yielding conflicting results. For instance, van de Poel, O'Donnell, and van Doorslaer (2012) used difference-in-differences estimators to assess the impact of urbanization on health. They found that urbanization has a substantial and negative impact on health, principally

[1] Some 21% of households with out-migrant workers choose to embrace RCenR, while 23% of households without out-migrant workers choose to embrace RCenR. Therefore, the presence of migrant workers has a relatively small impact on the choice of RCenR for households.

[2] Calculated by the authors of this study using China Family Panel Studies 2016 survey dataset. The data is from the China Family Panel Studies (CFPS), funded by the 985 Program of Peking University and carried out by the Institute of Social Science Survey, Peking University, 2015, China Family Panel Studies (CFPS), https://doi.org/10.18170/DVN/45LCSO, Peking University Open Research Data Platform, V42: [CFPS Public Data] CFPS 2016_in_STATA_(Chinese).rar.

[3] Calculated by the authors of this study using China Family Panel Studies 2016 survey dataset (China Family PanelStudies, 2016). See Footnote 3.

because it results in unhealthy lifestyles, such as the increased tendency to smoke and eat unhealthy food. In contrast, Liu, Wu, Peng, and Fu (2003) found that urbanization provides rural residents with access to better education, higher income, and higher level of medical insurance, thereby improving their health. Like urbanization, RCenR can also improve local infrastructure, exerting a significant impact on the lifestyle of rural residents. RCenR can protect the existing cultivated land and support the development of agriculture. They also improve the living environment of rural households by consolidating rural homesteads and thus may improve the health of rural residents in general.

Although several studies address the impact of RCenR on gross income (Liu, Zhang, & Lo, 2014; Ong, 2014), employment (Palmer, 1988; Paquette & Domon, 2001), and social communication (Zhang, Wu, Zhong, Zeng, & Wang, 2017; Zhao & Zou, 2017), the impact of RCenR on the health of rural residents remains relatively unexplored. This study contributes to the literature in several ways. First, most prior studies have examined left-behind children, older people, and women. This study is the first to examine the effect of RCenR on the health of the acting heads. Second, the study employs an IV to address potential endogeneity biases, ensuring the robustness of the study. Third, it explores the possible channels through which RCenR affects the health of the acting heads. It is found that RCenR improves their health by increasing income, promoting households to shift from agricultural activities to non-agricultural activities or employment, increasing the use of clean energy and clean water, and facilitating access to medical services. These findings are important because they can assist developing countries to improve their rural development policies.

The remainder of this study is organized as follows. Section 2 discusses the possible channels through which RCenR affects the health of the acting heads. Section 3 describes the background of RCenR. Section 4 presents the data and descriptive statistics. Section 5 presents the study's identification strategy and the estimation results. Section 6 contains the concluding remarks.

2. Conceptual framework

One obvious channel through which RCenR may affect the health of the acting heads is an improvement in income. The population aggregation and the infrastructure improvements brought about by RCenR may boost the local business environment, prompting many households to engage in non-agricultural activities or employment, such as running kiosks or mahjong parlors (Li, Liu, Long, & Cui, 2014; Liu & Zhou, 2022; Xu, Tang, & Chan, 2011). Liu, Wang, et al. (2020) find that RCenR in China increases the time spent by households on non-agricultural activities, thereby augmenting their income. A significant increase in household income is expected to have a positive effect on the health of acting heads. First, a higher income enables households to make a greater investment in health, such as adopting a better diet (Allcott et al., 2019; Barham & Rowberry, 2013; Grossman, 1972). Second, a higher income allows households to afford better quality healthcare (Ghosh, Simon, & Sommers, 2019; Grossman, 1972; Kim & Koh, 2021). Third, the increase in non-agricultural income may also prompt households to abandon strenuous farming (Kim & Koh, 2021).

As stated above, RCenR may prompt the transition of households from agricultural to non-agricultural activities or employment. Liu and Zhou (2022) find that RCenR in China significantly increases local employment opportunities and encourages households to engage in business activities. Non-agricultural activities or employment enables households to reduce or cease subsistence farming, thereby reducing or avoiding strenuous agricultural activities, which can take a heavy toll on health (Mu & van de Walle, 2011; Shen, Fang, & Zheng, 2022).

Moreover, RCenR may improve access to clean energy and tap water. A strand of literature has shown that RCenR can improve local public infrastructure, such as energy and water infrastructure (Lerise, 2000; Liu, Yang, Zhong, Sissoko, & Wei, 2018). For example, Liu, Wang, et al. (2020) report that RCenR can assist households to switch from non-clean energy to clean energy in rural China. Studies in related disciplines, such as health, economics, and medicine, have shown that water quality (Jalan & Ravallion, 2003; Kremer, Leino, Miguel, & Zwane, 2011; Mettetal, 2019) and clean energy (Hou et al., 2022; Imelda, 2020; Zhang, Li, & Han, 2019) significantly contribute to health. Zhang (2012) notes that improved water quality reduced the incidence of illness in adults and increased the height and weight of adults and children. Liu, Li, Rommel, and Feng (2020) indicate that the use of clean energy for cooking improves the health of older people in China.

Another way in which RCenR may affect the health of the acting heads is through better access to local health services. Numerous studies have shown that improved medical services have a positive effect on health (Bailey & Goodman-Bacon, 2015; Cesur, Güneş, Tekin, & Ulker, 2017; Hammer & Spears, 2016; Lavy, Strauss, Thomas, & De Vreyer, 1996). RCenR increases the density of the population, making it easier and less costly to provide medical services. Liu, Yang, Liu, Wei, and Yang (2018) state that RCenR leads to significant spatial reconstruction. This facilitates the establishment of public services that are more convenient, including medical services.

3. Background

Scattered settlement patterns have long contributed to the decline of rural areas, and have been associated with inadequate land use, declining water quality, increasing difficulty in providing adequate public infrastructure and services, and reduced employment opportunities (Gkartzios & Scott, 2009; Higgs & White, 2000). In addition, with China's rapid urbanization and industrialization, the rural population has begun a mass exodus to cities, thereby accelerating the decline of rural areas (Bai, Shi, & Liu, 2014; Long, Li, Liu, Woods, & Zou, 2012). To make better use of land destined for construction and integrate urban and rural development, China began to implement centralized residences in rural areas (Tang, Mason, & Sun, 2012; Yan, Xia, & Bao, 2015).

In China, rural farmland is collectively owned and cannot be traded, which results in fallow land or inefficient use of rural construction land (Willaing, 2018). In 2004, the State Council issued the “Decision Deepening Reform and Enforcing Management of Land.” This decision linked the increase in urban construction land with the decrease in rural construction land (increasing vs.

decreasing balance policy), promoting the consolidation of rural construction land. This has increased the popularity of RCenR in China. In most cases of RCenR projects, the government has provided communities with supporting infrastructure, including clinics, schools, running water, and natural gas, which have profoundly changed the way of life of rural residents. In addition, the construction of larger communities has generated employment or business opportunities for farmers, such as the establishment of inns, mahjong parlors, and shops. These efforts not only greatly improved the living environment in rural areas, but also effectively curbed the decline of rural areas by revitalizing villages.

Sichuan province began the large-scale implementation of RCenR in 2005. To reduce the cost burden of relocation and encourage more households to embrace RCenR, the government grants a housing subsidy based on certain rules for those households who choose to move to an RCenR community. The subsidy rules are set in advance by the government and are announced before the construction of the RCenR. The rules are *deterministically* based on two pre-RCenR household characteristics. The first is the number of family members with local agricultural *hukou* (registered permanent residence) that a household had usually one year before the RCenR initiative announcement (the variable of *Pre-RCenR family size*). The second is the size of original housing area *approved* officially by the government when original housing was built (which is used to generate the variable of *Logarithm of pre-RCenR housing area*). Regardless of whether a household moves to an RCenR community ultimately, the local management team and the relevant household together will calculate the amount of the once-off government housing subsidy (in Chinese *yuan*) it will receive before the household decides whether or not to move to an RCenR community. The logarithm of the sum of the housing subsidy and one is the IV used in this study – the variable of *Sub_RCenR*. It can be assumed that households receiving a greater housing subsidy will be more likely to move into an RCenR community (see Liu, Wang, et al., 2020 for more details).

4. Data and descriptive statistics

4.1. Overview

The primary data used for the analysis are based on a rural household survey carried out in Sichuan province in 2017. In total, 3551 households were interviewed and observed from 105 villages in 20 counties.

The survey questionnaire contains more than 300 items. The contents of the questionnaire included characteristics of the acting heads and family members; housing and land characteristics; location information before and after RCenR; subjective evaluation of infrastructure or public services; household income and expenditure; and the economic and geographical environment of the village. The data used in this study include the health information of the acting heads as well as other detailed individual characteristics, such as gender, age, and education. Information on the characteristics of families and villages was also included. Moreover, the data contained information about the RCenR, such as the construction time and location before and after RCenR.

As mental and physical health are interlinked (Ruo, Rumsfeld, Liu, Browner, & Whooley, 2003), the survey used the subjective health status of the acting heads as the primary health outcome in this study. Self-assessed health is a good indicator of overall health status, and has an adequate predictive capacity for future disease incidence and life expectancy (Hertzman, Power, Matthews, & Manor, 2001; Idler & Benyamini, 1997; Power, Manor, & Fox, 1991; Wannamethee & Shaper, 1991). The responses are recorded using

Table 1
Descriptive statistics.

Variables	(1)	(2)	(3)	(4)
	Means			
	Full sample	RCenR	Non-RCenR	Columns 2–3
A. Outcome Variable				
Head health	0.548	0.601	0.533	0.068***
B. Variable of Interest				
RCenR	0.218			
C. Instrumental Variable				
Sub_RCenR	5.943	10.33	4.721	5.613***
D. Control variables				
Head age	55.03	54.06	55.30	−1.237**
Head gender (male = 1)	0.521	0.519	0.522	−0.003
Head with middle school diploma or above (yes = 1)	0.419	0.466	0.406	0.059***
Pre-RCenR family size	3.921	3.678	3.989	−0.311***
Number of children under 6 years old	0.262	0.274	0.259	0.0150
Number of disabled people	0.375	0.404	0.367	0.0370
Logarithm of pre-RCenR housing area	5.205	5.177	5.213	−0.0370
County class or above road nearby (yes = 1)	0.541	0.622	0.518	0.103***
Whether there are firms nearby (yes =1)	0.848	0.878	0.840	0.037**
Mountain area	0.430	0.501	0.410	0.091***
Observations	3267	711	2556	3267

Note: This table reports descriptive statistics for the whole sample, the RCenR and the non-RCenR samples.
*** Significant at the 1% level.
** Significant at the 5% level.

a five-point Likert scale ranging from 1 to 5 (corresponding to "very bad," "bad," "neutral," "good," and "very good"), with the higher scores indicating better health. This study follows the health literature to classify "very good" and "good," as healthy (the dummy variable of *Head health* equals 1) and the rest as unhealthy (*Head health* = 0) (Bullinger, 2019; Finkelstein et al., 2012). It also uses a continuous dependent variable for health status as a robustness check.

4.2. Sample selection

The study employs the concept of a cross-prefecture contiguous-villages group (Cross-Pre-Vil-Group). A Cross-Pre-Vil-Group consists of several (two in most cases) cross-prefecture contiguous administrative villages bordering one another geographically. They share the same cultural habits and a similar economic and geographical environment. It is contended that unobserved factors are identical in the same Cross-Pre-Vil-Group.

The sampling procedure is as follows. First, the border towns on the Chengdu side are selected, using the number of towns in the administrative unit as the sample weight. Second, the border villages on the Chengdu side are selected. Third, the corresponding border villages on the non-Chengdu side are determined. Finally, a certain number of rural households is randomly selected in each village. This study refers the readers to Liu et al. (2020b) for more details on the sampling procedures used in this article.

4.3. Descriptive statistics

Owing to missing data, the final baseline sample comprises 3267 rural households, for which all relevant information is available. Table 1 presents the descriptive statistics for the full sample in the baseline analysis. The study provides descriptive statistics for households that chose to embrace RCenR (Column 2) and those that did not (Column 3). Column 4 shows the sample mean differences between the two groups. With respect to the outcome variable (*Head health*), 54.8% of rural residents are healthy in the full sample. When considering unconditional mean differences, RCenR seem to have a significantly positive relationship with the health of the acting heads.

Regarding the IV (*Sub_RCenR*), RCenR households receive a higher housing subsidy than non-RCenR households. This is a preliminary indication that expected housing subsidies are predictive of whether households will choose to embrace RCenR. The acting heads of RCenR households are more likely to be younger (the variable of *Head age*), and have a middle school diploma or higher qualifications (the variable of *Head with middle school diploma or above*) than acting heads in non-RCenR households. There are no significant differences in terms of gender of the acting heads (the variable of *Head gender*) between RCenR and non-RCenR households.

5. Identification strategy and empirical results

5.1. Identification strategy

If RCenR were an exogenous variable, the following ordinary least square (OLS) model would accurately estimate the impact of RCenR on the health of the acting heads:

$$H_{ijk} = \beta_0 + \beta_1 RCenR_{ijk} + X_{ijk}\beta_2 + \omega_k + \varepsilon_{ijk}, \tag{1}$$

where H_{ijk} is the outcome of interest (the health of the acting heads) for acting head i in village j in cross-prefecture contiguous-villages group k. $RCenR_{ijk}$ is an indicator variable for whether the household chooses to embrace RCenR. X_{ijk} is a set of characteristics of acting head and his/her household, while ω_k is a cross-prefecture contiguous-villages group fixed effect (Cross-Pre-Vil-Group FE), and ε_{ijk} denotes the error term.

To mitgate endogeneity concerns, the study controls for Cross-Pre-Vil-Group FE in this specification. Contiguous villages have the same customs and similar economic and geographical environments, some elements of which cannot be accurately observed and measured. Controlling these fixed effects reduces endogeneity biases. However, the OLS estimation of Eq. (1) may be still biased by endogeneity. In this study, selectivity bias may be positive or negative. Some unobservable factors, such as the preference of the acting heads for a healthy lifestyle and environment, may contribute to their good health. Such preferences and habits may also encourage them to move into an RCenR community, where the environment is healthier and the medical service is more convenient. Alternatively, poor health may encourage rural residents to choose an RCenR community to obtain access to better medical resources. Moreover, unobserved complex local, natural, geographical, and human environments may also influence the choice of whether or not to embrace RCenR, and thus, the health of the acting heads. Consequently, this may lead to positive or negative selection bias.

To address this potential endogeneity, this study instruments the variable of *RCenR* using the expected once-off government housing subsidy (*Sub_RCenR*) while conditional on the control variables including the two subsidy-determining pre-RCenR household characteristics. It estimates the causal impact of RCenR on the health of the acting heads using two-stage least squares (2SLS). The first-stage and reduced-form specifications are as follows:

$$RCenR_{ijk} = \alpha_0 + \alpha_1 Sub\_RCenR_{ijk} + X_{ijk}\alpha_2 + \mu_k + \theta_{ijk,} \tag{2}$$

$$H_{ijk} = \gamma_0 + \gamma_1 Sub\_RCenR_{ijk} + X_{ijk}\gamma_2 + \pi_k + \vartheta_{ijk,} \tag{3}$$

where μ_k and π_k are Cross-Pre-Vil-Group FE, and θ_{ijk} and φ_{ijk} are idiosyncratic error terms. If the proposed IV is valid and the effects are

heterogenous, the above 2SLS approach identifies the local average treatment effect (Imbens & Angrist, 1994) of the compliers. In this study, the compliers are those who were influenced by the expected housing subsidy to embrace RCenR. Studies on the effect induced by compliers have important policy implications. The robustness of the conclusions of this study depends on the validity of the IV, which is examined in greater detail in Section 5.2.

5.2. Validity of the IV

First, the IV should significantly influence the likelihood of households to embrace RCenR. Column 1 of Table 2 reports the first-stage regression results, which show that *Sub_RCenR* has a strong predictive capacity for choosing RCenR. The study also performs weak IV tests on *Sub_RCenR*. F test statistic of excluded instruments is 52.59, which is larger than 10 of the conventional level. Cragg-Donald Wald F statistic is 330.90. It is far larger than 16.38, the Stock-Yogo weak IV test critical value of 10% maximal IV size. Both statistics indicate that our IV is not weak. These results consistently confirm that *Sub_RCenR* is highly predictive of the decision to embrace RCenR. Column 2 of Table 2 reports the reduced-form results. The coefficient of *Sub_RCenR* is significantly positive, indicating that expected housing subsidy can positively affect the health of the acting heads.

In addition, the IV must also satisfy the exclusion restriction assumption. The exclusion restriction assumption implies that *Sub_RCenR* only affects head health through *RCenR*. A common method to partially check this assumption is to identify a specific subsample whose first-stage result is insignificant, and then verify whether its reduced-form result is also insignificant (Angrist, Lavy, & Schlosser, 2010). Therefore, this study conducts this check using households whose original houses were built in the last 10 years and whose original average per capita housing area exceeds 70 square meters. Since RCenR requires a considerable expenditure, rural households with newer original houses are less likely to move. Governments stipulate that the per capita housing area of RCenR communities shall not generally exceed 35 square meters. For these households, the sharp reduction in the per capita housing area may undermine their willingness to choose RCenR. Therefore, the first-stage result of this subsample should be close to zero. If this assumption holds, there should be no statistically significant reduced-form relationship between *Sub_RCenR* and the health of the acting heads in this subsample. Table 2 shows the first-stage and reduced-form results for this subsample. The result of the first-stage is insignificant statistically (Columns 3). Similarly, it shows that the coefficient of *Sub_RCenR* in the reduced-form is also insignificant statistically (Columns 4). This subsample check provides no evidence that the exclusion restriction is violated.

This study further refers to the method of Conley, Hansen, and Rossi (2012) to examine the sensitivity of the IV. It relaxes the strict exclusivity assumption of the IV (*Sub_RCenR*) and treats *Sub_RCenR* as plausibly exogenous. The study assumes that in addition to the RCenR, the coefficient gamma (λ) range of IV influence on the outcome variable through other channels is between [−0.001, 0.001].[4] Fig. 1 shows the union of confidence interval (UCI) of *RCenR* coefficient for this setting. The result shows that the UCI of *RCenR* coefficient in the case of plausibly exogenous cases is [0.0065, 0.2841], which is beyond zero.

Furthermore, the study uses a latest and increasingly popular econometric advancement to conduct the second sensitivity analysis (Cinelli, Ferwerda, & Hazlett, 2020; Cinelli & Hazlett, 2020, 2022). When the first stage is positive and highly significant, all that is needed is to assess the strength of unobserved confounders (violation of independence assumption) and side-effects (violation of exclusion restiction assumption) in the reduced-form regression (Cinelli & Hazlett, 2022), namely, the effect of *Sub_RCenR* on *Head health* in this study. The note in Table 3 presents the four variables that, of all the control variables, have the highest bias-adjusted critical threshold values, $t^{\dagger max}_{\alpha,\, df-1,\, R^2}$. Take as an example the variable of *Logarithm of pre-RCenR housing area*, which has the highest $t^{\dagger max}_{\alpha,\, df-1,\, R^2}$. The maximum strength of unobserved confounding variables, if they were as strong as *Logarithm of pre-RCenR housing area*, has $t^{\dagger max}_{\alpha,\, df-1,\, R^2} = 2.0850$, which is less than the observed *t*-value (2.1498). Table 3 indicates that confounding factors as strong as the variables of *Logarithm of pre-RCenR housing area, Head gender, Number of children under 6 years old* and *Number of disabled people* and the other control variables in Table 1 are not sufficiently strong to be problematic. The values of $t^{\dagger max}_{\alpha,\, df-1,\, R^2}$ for the other control variables are even lower, for example, $t^{\dagger max}_{\alpha,\, df-1,\, R^2} = 1.9114$ for the variable of *Head age* (for the reference, the mean and the standard deviation of *Head age* is 55.03 and 12.16 respectively in the survey). It is hard to find a story with an unobserved variable which influences the health of acting heads more than these control variables.

5.3. Primary results

Table 4 reports the OLS and IV results of the effect of RCenR on the health of the acting heads. In Columns 2 and 4, the study includes the Cross-Pre-Vil-Group FE. The standard errors are clustered at the village level. The OLS estimates suggest that RCenR significantly improves the health of the acting heads. The result in Column 1 shows that RCenR increases health by 5.9 percentage points. The coefficient of *RCenR* is slightly smaller, when adding the fixed effects in Column 2. The IV estimates are substantially larger than the OLS estimates, and confirm that RCenR improves the health of the acting heads. The result reported in Column 4 indicates a 17.1 percentage points significant improvement in health if households move to RCenR communities. The coefficient size of RCenR in this paper is comparable to those found in some relevant studies on health. Specifically, the results from Coe and Zamarro (2011) and Kim and Koh (2021) are cited as examples. For instance, Coe and Zamarro (2011) found that the retirement leads to a 35 percentage points decrease in the occurrence of bad health. Similarly, Finkelstein et al. (2012) demonstrated that access to public health insurance significantly improved health by 13.3 percentage points. These results suggest that the coefficient size of RCenR (0.171) found in our

[4] The size of 0.001 is 20% of the reduced-form coefficient (0.005) for full sample. See Column 2 in Table 2.

Table 2
Instrument variable validity tests.

	Dependent variable			
	RCenR (Full sample) (First-stage)	Health (Full sample) (Reduced form)	RCenR (Sub-sample) (First-stage)	Health (Sub-sample) (Reduced form)
	(1)	(2)	(3)	(4)
Sub_RCenR	0.031***	0.005***	0.005	−0.000
	(0.005)	(0.002)	(0.003)	(0.009)
Demographic characteristics controls	Yes	Yes	Yes	Yes
Village characteristics controls	Yes	Yes	Yes	Yes
Cross-Pre-Vil-Group FE	Yes	Yes	Yes	Yes
F test of excluded instruments	52.59	–	–	–
Cragg-Donald Wald F statistic	330.90			
Observations	3267	3267	264	264
R-squared	0.406	0.143	0.531	0.307

Notes: Robust standard errors clustered at the village level. Columns 1 and 2 report the results of the first-stage and reduced-form results for the full sample. Columns 3 and 4 report the results of the first-stage results and reduced-form results for the subsample of the exclusion restriction assumption check.
*** Significant at the 1% level.

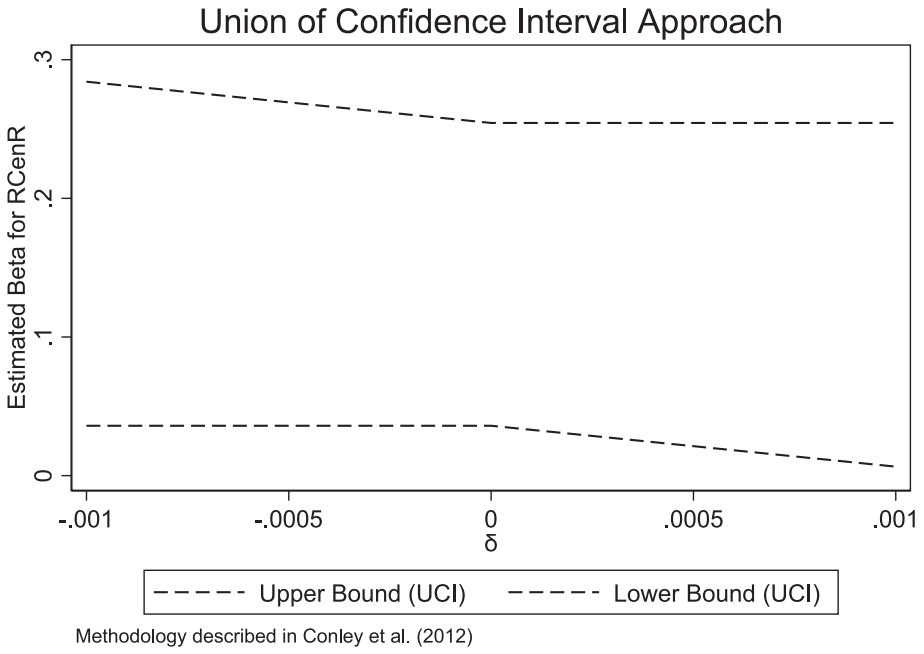

Fig. 1. Confidence interval based on the Union of Confidence Interval approach method.

Table 3
Minimal sensitivity reporting of the reduced-form regression (Outcome: Health).

Instrument	Estimate	Std. Error	*t*-value	$R^2_{D-Z\|\mathbf{X}}$	$XRV_q{}^*{}_{,\alpha}$	$RV_q{}^*{}_{,\alpha}$
Sub_RCenR	0.0053	0.0025	2.1498	0.0014	0.0373	0.0033

Note: Bound (1* Logarithm of pre-RCenR housing area): $t^{i\,max}_{\alpha,\,df-1,\,R^2} = \ = 2.0850$.
Bound (1* Head_gender): $t^{i\,max}_{\alpha,\,df-1,\,R^2} = 2.060$.
Bound (1* Number of children under 6 years old): $t^{i\,max}_{\alpha,\,df-1,\,R^2} = 2.0674$.
Bound (1* Number of disabled people): $t^{i\,max}_{\alpha,\,df-1,\,R^2} = 2.0199$.
df = 3204, $q^* = 1$, $\alpha = 0.05$.

Table 4
Effects of RCenR on the health.

	Dependent variable: Health			
	OLS results	IV results		
	(1)	(2)	(3)	(4)
RCenR	0.059**	0.046**	0.101*	0.171***
	(0.023)	(0.023)	(0.060)	(0.059)
Head age	−0.011***	−0.011***	−0.011***	−0.011***
	(0.001)	(0.001)	(0.001)	(0.001)
Head gender (male = 1)	0.076***	0.087***	0.076***	0.088***
	(0.017)	(0.018)	(0.017)	(0.018)
Head with middle school diploma or above (yes = 1)	0.091***	0.083***	0.089***	0.082***
	(0.020)	(0.020)	(0.019)	(0.019)
Pre-RCenR family size	0.014**	0.016**	0.016**	0.018***
	(0.006)	(0.007)	(0.006)	(0.006)
Number of children under 6 years old	−0.021	−0.019	−0.022	−0.024
	(0.019)	(0.019)	(0.019)	(0.019)
Number of disabled people	−0.059***	−0.057***	−0.060***	−0.061***
	(0.012)	(0.012)	(0.012)	(0.012)
Logarithm of pre-RCenR housing area	0.014	0.015	0.015	0.016
	(0.017)	(0.019)	(0.017)	(0.019)
County-class or above road	0.020	−0.008	0.016	−0.027
(yes = 1)	(0.021)	(0.023)	(0.022)	(0.026)
Whether there are firms nearby (yes = 1)	0.055**	0.057	0.052**	0.049
	(0.025)	(0.036)	(0.024)	(0.032)
Cross-Pre-Vil-Group FE	No	Yes	No	Yes
Exogeneity test *F*	–	–	–	4.038
(*p*-value)				(0.047)
Observations	3267	3267	3267	3267
R-squared	0.115	0.143	0.114	0.136

Notes: Robust standard errors clustered at the village level. Columns 1 and 3 report the results obtained controlling for the demographic and village characteristics. Columns 2 and 4 add Cross-Pre-Vil-Group FE.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

study is of similar magnitude to those reported in other important studies on health. The substantial differences between the IV and OLS estimates indicate the presence of endogeneity. The study performs the endogeneity test, and the *F* value of 4.038 (*p*-value = 0.047) also confirms the endogeneity. This result proves the rationality of the proposed identification strategy.

5.4. Heterogeneity analysis

Table 5 reports the heterogeneity of the effects of RCenR on the health of the acting heads for left-behind and non-left-behind households. The results showed the effect of RCenR for left-behind household group is significant statistically but the effect of RCenR for non-left-behind household group is not. And the size of the coefficient for the group of left-behind households is larger. One possible explanation for this result is that the RCenR can promote the return of out-migrant workers (who may or may not include the registered family head) (Liu & Zhou, 2022). Those returnees may take some responsibilities which otherwise were taken by the left-behand household members including the acting heads. The discharge of some responsibilities improves the health of the acting heads

Table 5
Heterogeneity results for left-behind and non-left-behind households.

	Dependent variable: Health	
	Left-behind households	Non-left-behind households
	(1)	(2)
RCenR	0.271***	0.050
	(0.075)	(0.094)
Demographic characteristics controls	Yes	Yes
Village characteristics controls	Yes	Yes
Cross-Pre-Vil-Group FE	Yes	Yes
Observations	1873	1394
R-squared	0.126	0.173

Notes: Robust standard errors clustered at the village level.
*** Significant at the 1% level.

of the left-behand households. Compared with non-left-behind households, the acting heads of left-behind households have greater pressure in terms of family affairs and farm work (Lei & Desai, 2021; Tong et al., 2019). In addition, rural labor out-migration also poses significantly health risks to the family members of left-behind households (Antman, 2010; Böhme et al., 2015; Huang, Lian, & Li, 2016; Lee, 2011). Consequently, the RCenR would lead to greater improvements in the health of heads of left-behind households.

5.5. Robustness checks

Table 6 reports the results of various tests performed to confirm the robustness of the study results. First, the study uses a continuous dependent variable for health status as the dependent variable. The IV results for this setting are reported in Column 1 of Table 6. It is found that the coefficient of RCenR is still significantly positive. Second, this study uses the ordered logit model to analyze the effect of RCenR on the health of the acting heads. The results in Column 2 of Table 6 show that the results are robust. Third, in some cases, such as the implementation of major projects and environmental protection initiatives, entire villages are relocated to RCenR communities. These exceptional cases may affect the study results; therefore, the study discards them and reassesses the impacts of RCenR. Column 3 of Table 6 shows the result, which is slightly higher than the primary result but still robust. Fourth, the key assumption of the 2SLS method used to obtain the baseline result is that the error terms are homoscedastic. The study relaxes this assumption and assumes that the error terms are heteroscedastic. It then re-estimates the impact of RCenR using a generalized method of moments (GMM) approach under the heteroscedasticity assumption. The GMM estimates in Column 4 of Table 6 are similar to the baseline results.

An additional four robustness checks are conducted, with the results shown in Table 7. First, Chengdu Tianfu New Area may have some special policies that other regions do not have. Column 1 of Table 7 presents the results after excluding households in Chengdu Tianfu New Area. Second, the study uses the bi-probit model to estimate the effect of RCenR. The result for this setting is reported in Column 2 of Table 7. Third, the study regards two adjacent border towns located in Chengdu and on the non-Chengdu side as a cross-prefecture contiguous-towns group. Column 3 of Table 7 reports the results of controlling for these fixed effects. Fourth, this study clusters the standard errors at the cross-prefecture contiguous-villages group level to account for the possible correlation between households at this level (Column 4 of Table 7). The coefficients of RCenR in the above four robustness checks are all significantly positive, indicating that the results of the baseline analysis in this study are robust.

5.6. Possible mechanisms

This study further conducts the following analyses to explore the mechanisms through which RCenR affects the health of the acting heads. First, it examines the impact of RCenR on household income. As described in Section 2, RCenR may induce households to devote more time to non-agricultural activities, thereby increasing household income (Liu et al., 2020b). This study uses the logarithmic value of household income to measure their income. Column 1 of Table 8 presents the IV results for the relationship between household income and RCenR. The coefficient of *RCenR* is significantly positive, indicating that RCenR can improve the health of the acting heads by increasing their household income.

Second, the study investigates whether households in the RCenR communities are more likely to be engaged in business activities. RCenR brings people together, which helps develop commercial activities, such as convenience stores or mahjong parlors. In addition, RCenR may attract industrial parks through land consolidation, thereby, increasing demand for services and products. The study defines the variable of *business* as a dummy. The value of this variable is 1 when the household is engaged in business activities, and 0 otherwise. Column 2 of Table 8 shows that RCenR households are more likely to be engaged in business activities.

Another mechanism may be that RCenR is associated with the use of clean energy and clean water, which has a positive impact on health. RCenR promotes the consolidation of rural construction land, enabling the government to improve supporting infrastructure, which includes energy and water infrastructure. In addition, a higher income means that households can afford clean energy services.

Table 6
Robustness check results A.

	Dependent variable: Health			
	Continuous dependent variable	Ordered logit model	Exclude exceptional villages	GMM
	(1)	(2)	(3)	(4)
RCenR	0.371**	0.257**	0.179***	0.171***
	(0.150)	(0.102)	(0.056)	(0.056)
Demographic characteristics controls	Yes	Yes	Yes	Yes
Village characteristics controls	Yes	Yes	Yes	Yes
Cross-Pre-Vil-Group FE	Yes	Yes	Yes	Yes
Observations	3267	3267	3160	3267
R-squared	0.178	–	0.135	0.136

Notes: Robust standard errors clustered at the village level.
*** Significant at the 1% level.
** Significant at the 5% level.

Table 7
Robustness check results B.

	Dependent variable: Health			
	Exclude households in Tianfu New Area	Bi-probit model	Use a cross-prefecture contiguous-towns fixed effects	Clustered at the cross-prefecture contiguous-villages group
	(1)	(2)	(3)	(4)
RCenR	0.152***	0.468***	0.111*	0.171**
	(0.058)	(0.143)	(0.061)	(0.074)
Demographic characteristics controls	Yes	Yes	Yes	Yes
Village characteristics controls	Yes	Yes	Yes	Yes
Cross-Pre-Vil-Group FE	Yes	Yes	No	Yes
Observations	3169	3267	3160	3267
R-squared	0.138	–	0.133	0.136

Notes: Robust standard errors in Columns 1 to 3 are clustered at the village level; robust standard errors in Column 4 are clustered at the Cross-Pre-Vil-Group level.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

Table 8
Possible mechanism results.

	Dependent variable:	
	Income	Business
	(1)	(2)
RCenR	0.269***	0.254**
	(0.078)	(0.104)
Demographic characteristics controls	Yes	Yes
Village characteristics controls	Yes	Yes
Cross-Pre-Vil-Group FE	Yes	Yes
Observations	3267	3267
R-squared	0.311	0.118

Notes: Robust standard errors clustered at the village level.
*** Significant at the 1% level.
** Significant at the 5% level.

Liu, Wang, et al. (2020) demonstrated that RCenR significantly prompts households to choose clean energy. Besides, Row 1 of Table 9 shows tap water access for RCenR households and non-RCenR households. The data indicate that RCenR is significantly associated with higher probability of access to tap water. These results suggest that RCenR can improve the health of the acting heads by facilitating household to use cleaner energy and access to clean water.

Finally, this study examines the relationship of RCenR with local medical services. RCenR prompts the consolidation of rural construction land, enabling the government to improve supporting institutions, including medical facilities. The construction of medical facilities in RCenR communities decreases the distance between rural households and medical facilities. Row 2 of Table 9 shows the distance to the nearest hospital or clinic for RCenR households and non-RCenR households. The result shows that RCenR households are closer to the nearest medical facilities than non-RCenR households. This result suggests that RCenR may enable it easier for RCenR households to access to local medical services.

Table 9
t-test results for distance to the nearest hospital and access to tap water.

	Means		
	RCenR	Non-RCenR	Columns (1)–(2)
	(1)	(2)	(3)
Access to tap water	0.896	0.487	0.409***
Distance to the nearest hospital or clinic (kilometers)	1.370	1.892	−0.522***
Observations	711	2556	3267

Notes: The table reports the *t*-test results for distance to the nearest hospital or clinic and access to tap water.
*** Significant at the 1% percent level.

6. Conclusion

This study is the first to estimate the causal effect of RCenR on the health of acting heads of rural households. It exploits the expected once-off government housing subsidy as an IV for RCenR. The study results show that RCenR significantly improves the health of acting heads. The study further explores four possible mechanisms for the impact of RCenR on the health of the acting heads. First, RCenR can increase household income. Second, RCenR promotes the shift of households from agriculture to business activities. Third, RCenR enables household access to clean energy and clean water. Fourth, RCenR makes it easier for households to access to medical services.

The study provides robust empirical evidence on the impact of RCenR on the health of acting heads. These findings expand the current understanding of the welfare effect of RCenR. In addition, the findings have important implications for current rural revitalization policies in developing countries. First, the governments of these countries should invest more in medical facilities in rural areas. Second, governments should enhance water and energy infrastructure in rural areas because better access to clean water and clean energy can improve health. Third, governments should focus on job creation in rural areas and help residents to develop businesses according to the characteristics of rural areas, thereby increasing local employment opportunities.

Despite these crucial findings, this research has some limitations. Future studies could consider additional health indicators, such as specific scales of physical health and mental health. In addition, the impact of RCenR on the local employment market and lifestyle of the acting heads has important implications for the interpretation of the study results. These are open questions for future research, which could significantly improve the current understanding of the welfare effects of RCenR.

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Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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