The Effects of Lowering Blood Pressure on Income: Evidence from a Randomized Controlled Trial in Rural China

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Abstract

This paper explores the effects of lowering blood pressure on annual income. Health interventions can result in social welfare gains through improvements in both physical well-being and income. Previous literature has encountered difficulties in estimating the causal impact due to the endogeneity of health and the prevalence of employment contracts that limit income flexibility. Studying elderly farmers in rural China who need to perform un-mechanized farm work to make a living provides an opportunity for us to observe an unusually tight link between health, productivity, and income. Hypertension is one of the most prevalent chronic diseases in the world, but little is known about the impact of high blood pressure on labor market. The paper exploits data from a randomized controlled trial designed to improve hypertension management in a rural county in southwest China and utilizes the exposure to the interventions as an instrumental variable. We find that a one standard deviation decrease in systolic blood pressure can significantly increase annual income by 4.2%. The results of the cost-benefit analysis demonstrate that our interventions indeed resulted in large welfare gains.

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1 Introduction

Besides inflicting pain, poor health can also affect labor productivity and working hours, and therefore affect earnings. Health interventions, which improve both physical well-being and income, can result in social welfare gains. Understanding the causal relationship between health and income can better inform future health policies. There are two main challenges in estimating this causal relationship: first, because health is endogenous, any correlation found between health and income may be due to reverse causality or the effect of omitted variables. For example, healthier people can be more productive, which can lead to higher income; but productivity is often unobserved. In addition, individuals with higher income can in return have better access to health insurance and medical treatment and can avoid hazardous jobs, all of which leads to better health. One common omitted variable is the strenuousness of the work, which cause higher income and worse health but is hard to measure. Second, employment contracts often limit the flexible measures of income. Most papers focus on urban labor market, where wage workers can be sheltered from health shocks due to the prevalence of employment contracts. Thus there is little evidence in the literature on the effect of health on income directly, especially in the short run.

In this paper, we address the difficulties encountered by previous literature and study the labor market impact of health improvement among patients with high blood pressure. We exploit data from a randomized controlled trial designed to improve hypertension management in a rural county in southwest China. We utilize the exposure to the trial interventions as an instrumental variable to estimate the causal impact of lowering blood pressure on income. Our sample population consist of farmers who grow corn, tobacco, and other crops in the fields, harvest the crops, and sell them in local market. Since these farmers need to perform un-mechanized farm work to make a living, we observe an unusually tight link between health, productivity, and earnings that might be difficult to replicate in high-income societies.

High blood pressure is one of the most prevalent chronic diseases in the world and a main driver of the global burden of cardiovascular diseases. World Health Organization (2009) has named hypertension as the number one risk factor for mortality, with this disease being responsible for 13% of deaths globally. In China, for example, the prevalence of hypertension among adults almost doubled from 18% in 2002 to 34% in 2010 (Hou et al., 2016). Despite the prevalence of hypertension, little is known about high blood pressure?s impact on labor market outcomes.

In our data, six towns were randomly assigned into three groups: a control group with no interventions, group 1 with an integrated care model intervention, and group 2 with both the integrated care and financial interventions. Both interventions are designed to improve care delivery and reduce costs for patients with hypertension, and are successful at hypertension control, as measured by the systolic blood pressure. Thus, the trial provides an exogenous shock to the blood pressure level and we utilize the exposure to the interventions as instruments to infer causality between health and income.

Using the instrumental variables approach, we find that lowering blood pressure increases income: specifically, one standard deviation decrease in systolic blood pressure (9.54 mmHg) significantly increases income by 4.2% among farmers. Using placebo tests, we show that this effect is not driven by remittances or government subsidies. We examine the channels through which hypertension could affect income and find that the increase in income resulted from an improvement in labor productivity rather than from longer working hours. We also conduct a cost-benefit analysis showing that the gain from increased income is much larger than the cost of the interventions.

The exclusion restriction assumption of the instrumental variables approach require that both interventions are uncorrelated with the unobservables and only affect patients? income by affecting their health. Because two interventions were randomly assigned, the instrumental variables are uncorrelated with unobservables like patients? working hours and work strenuousness. Moreover, the interventions were targeted on healthcare providers rather than on patients, so the effect on patients' income can only come from changes in patients' health. We address remaining caveats related to the verification of the identification strategy in Section 5.2.

Our study contributes to the literature in several ways. First, estimating the causal effect of health on income is difficult because health is endogenous; our paper utilizes an instrumental variables approach and data from a randomized controlled trial that enables us to identify causality. The literature examining the relationship between health and labor market outcomes mostly focuses on correlation rather than causality, both at the macro level (Arora, 2001; Weil, 2007) and at the micro level (Bartel and Taubman, 1979). Among the papers that aim to estimate the causal effect of health on labor market outcomes, some use a dynamic programming model (Bound et al., 2010), some use panel data and individual fixed effect (Wagstaff, 2007; Pohl et al., 2014), and others use sudden health events (Halla and Zweimüller, 2013). They found large impact of health on labor market behavior.

Second, our paper is one of few studies that provides direct empirical evidence on the effect of health on direct measure of income. Because employment contracts limit the flexible measure of income, there is little evidence on the direct effect of health on income. The literature tends to measure income lost by an output decrease due to sickness and disability and evaluate outcomes such as employee disability days, early retirement, and unemployment. However, not all diseases can be well-characterized simply by absenteeism (Bleakley, 2010), and a direct measure of productivity—such as income—is more preferable. In our paper, we focus on rural self-employed farmers who need to perform un-mechanized farm work to make a living. Thus their income is very responsive to the changes in their physical well-being.

Third, our study is one of the first to measure the effect of health *improvement*, instead of health *impairment*, on income, in low or middle income countries. Most studies on the labor market impact of health focus on developed countries, by studying the incidences of severe health impairments, such as workplace accidents and road injuries (Dano, 2005; Halla and Zweimüller, 2013). However, study of health improvement, which has more direct policy implications, is rarely seen. In this paper, we fill the gaps in the literature by focusing on rural labor market in a developing country and looking at the effect of hypertension control on income. It is particularly important to study hypertension, because effective and relatively inexpensive anti-hypertension treatments have been around for more than 50 years so potential welfare gains from hypertension interventions can be large.

Fourth, we use both objective and subjective measures of health. Many previous papers use subjective measures such as self-assessed health status, that are often associated with errors. Wu (2003) argues that subjective health measures can be confounded, since an individual may simply feel better physically when the household is financially better off. We get around this issue by measuring the severity of hypertension with systolic blood pressure, which is objective and precise. Clinical trials have demonstrated that control of systolic hypertension decreases the risk of diseases such as heart failure and stroke (Izzo et al., 2000; Trialists' Collaboration et al., 2008). In addition, we use a subjective measure—RAND's SF36 score—to rule out the possibility that our findings are driven by other improvements in health besides blood pressure.

The rest of this paper is organized as follows: Section 2 introduces the institutional background and Section 3 provides the details of the randomized controlled trial. Section 4 presents data and measurements. Section 5 illustrates the empirical strategies. Section 6 presents results, and Section 7 concludes.

2 Hypertension and Institutional Background

Our intervention sites are located in Qianjiang county, a rural district in China with a population of 545,000. It is located 280 kilometers south east of Chongqing, one of China's four province-level municipalities (Figure 1). Qianjiang has 30 town centers, each surrounded by around 10 villages. Of these towns, 80% are rural, and 91% of the individuals in our sample reported that they work in farming. The average annual per capita income for rural residents was 6,215 RMB (around 1,035 USD) in 2012. Qianjiang is representative of China's rural areas in terms of its population size, economic development level, and chronic disease prevalence (Tang, 2015).

2.1 Hypertension: Risk and Management

Hypertension is defined as having a systolic blood pressure above 140 or a diastolic blood pressure above 90 mmHg as calculated by the averaging of two or more properly measured readings (Chobanian et al., 2003).

High blood pressure, which affects nearly one billion people worldwide, is a prevalent public health problem and is the leading risk factor for cardiovascular disease globally (Wu et al., 2008). In recent years, it has become more of a serious problem in developing countries. In the middle and low income countries, the overall prevalence rate of hypertension among the general population is about 32.3% (Sarki et al., 2015). In China, the prevalence of hypertension among adults almost doubled from 18% in 2002 to 34% in 2010 (Hou et al., 2016). It now affects over 442 million people in China and is estimated to cause 20% of deaths in China (Feng et al., 2014).

Uncontrolled hypertension can cause serious damages to the heart and coronary arteries, and increase the likelihood of heart attack, stroke, kidney disease, disability, and shortened life expectancy (Stamler, 1998). Aggarwal and Khan (2006) shows that even a slightly elevated blood pressure can increase the risk of cardiovascular disease. Hypertensive crisis, systolic blood pressure rising above 180 mmHg, can also cause severe headache, shortness of breath, and severe anxiety. Ezzati et al. (2005) suggests that high blood pressure accounts for about 45% of global cardiovascular disease morbidity and mortality. In rural China, because of poor hypertension management, the rate of uncontrolled blood pressure is much higher than that in the West, estimated to be 63.4% in 2012 among Chinese with hypertension (Hou et al., 2016). In our sample, 53.4% individuals have had inpatient stays, 21.0% of which were hypertension-related.

Treatment of hypertension usually combines nonpharmacologic therapy and anti-hypertensive drug therapy. Nonpharmacologic therapy is also called lifestyle modification, including limiting dietary salt intake, limiting alcohol intake, increasing daily exercise, etc. Anti-hypertensive drugs can be classified into four categories: diuretics, calcium channel blockers (CCB), angiotensin-converting enzyme inhibitor (ACEI), and angiotensin receptor blockers (ARB). The anti-hypertensive drugs prescribed by the doctors in our trial came exclusively from the National Essential Medicine List (2012 edition) released by the China Food and Drug Administration, and all belong to one of the four categories.[1] Multiple studies have shown that all of the drugs on this list are effective in reducing blood pressure, and it is the degree of blood pressure reduction, rather than the choice of medication, that matters the most for the reduction of cardiovascular risk for hypertensive patients (Trialists' Collaboration et al., 2008). Trialists' Collaboration et al. (2014) also shows that the benefits of blood pressure-lowering drugs are proportional to the baseline cardiovascular risk. The average baseline systolic blood pressure level for the treatment groups is high—145.8 mmHg, hence the interventions can reduce cardiovascular risk sharply through ensuring medication adherence.

2.2 Usual Care in Rural China: The Three-Tier Healthcare System

Rural residents in China receive care from a village-town-county three-tier health care delivery system, corresponding to the three-tier administrative hierarchy (Zhang et al., 2016). Village level medical care is typically provided by an individual clinician, who sometimes sets up the clinic at his/her home. The clinician provides simple outpatient care, preventive care, and health care education to all villagers. The village clinic has a small supply of medications but often lacks rudimentary medications included in the National Essential Medicine List. At the town level, there is usually one infirmary that provides both outpatient and inpatient care.

[1] The National Essential Medicine List (2012 edition) includes the following anti-hypertension drugs: Captopril, Enalapril, Valsartan, Sodium Nitroprusside, Magnesium Sulfate, Nitrendipine, Nifedipine, Amlodipine, Bisoprolol, Indapamide, Phentolamine, Compound Reserpine, Compound Hypoensive, and Prazosin.

If town hospitals cannot treat the patient's illness, the patient can choose to go to hospitals in the county seat depending on his/her financial situation. As one goes up the three tiers, the health care professionals become more experienced and the services more expensive.

Most rural residents in China now have health insurance through the New Rural Cooperative Medical Scheme. Under the current system, most patients can go to county seat hospitals directly without going through town hospitals, but the inpatient reimbursement rate is much lower at the county level. For example, in Qianjiang in 2012, the inpatient policy reimbursement rate was 70% for services provided in the town hospitals and 55% for those in the county seat hospitals.

2.3 Labor Market in Rural Qianjiang

In the six towns in Qianjiang participating in our study, around 70% of the workforce works in agriculture.[2] Among senior residents, this percentage is even higher. In our sample, 90% reported their occupations to be farmers. They grow crops such as rice, corn, and tobacco, consume some as daily provision, and sell the rest as retailers on the local market. Thus their labor income depends entirely on the value of the agricultural products that they sell. Since they need to work in the fields and sell the products in the market, physical well-being can be positively related to production and income.

The major agriculture products in Qianjiang are grain (rice, corn, beans, etc.), tobacco, oil-bearing crops (peanut and rapeseed), and vegetables. In 2012 and 2013, the average annual production was 249,989 tons of grain, 8,810 tons of tobacco, 15,218 tons of oil-bearing crops, and 176,822 tons of vegetables. Overall, 33% of the grain, 79% of the vegetables, and around 80% of the tobacco and oil-bearing crops were sold as commodities on the market.[3]

For our participants, other forms of income in addition to labor income include pension

[2] This number is calculated using data from The China National Bureau of Statistics (2012).

[3] All the numbers were calculated using data from Chongqing Bureau of Statistics (2014). The commodity rate for each product in Qianjiang was not available so I report the average rate for Chongqing instead. The overall commodity rate in Qianjiang (69.5%) is not very different from the average in Chongqing (63.2%).

and other government subsidies and family support such as remittance from their children working in the city. However, a large percentage of rural elderly are heavily relied on their own labor income and continuing to work until they are physically incapable to do so. Davis-Friedmann (1991) describe this retirement pattern as "ceaseless toil." Based on the 2009 China Health and Nutrition Survey and the 2008 China Health and Retirement Longitudinal Study, Giles et al. (2011) found that at national average, over 65% of men and 40% of women still continue to work at the age of 70. The Chongqing Bureau of Statistics (2005) reported that 50.37% of Chongqing rural residents above 60 years old have labor income as their major source of income, 42.04% mainly depend on family support, and 4.81% mainly receive government support. The implementation of the New Rural Social Pension in 2012 can potentially encourage retirement among rural elderly, but the basic pension benefit is limited and our sample still shows high labor market participation rate.

In summary, for our sample—senior rural farmers—poor health can quickly have an impact on agricultural production, meaning income is highly dependent on and responsive to physical well-being.

3 Interventions

This randomized controlled trial has been registered at the World Health Organization's International Clinical Trials Registry Platform (ChiCTR-OOR-14005563) and was funded by the China Medical Board (Grant # 11-069). Two interventions were implemented: an integrated care model started in August 2012, and a financial incentive contract model started in June 2013. Both interventions ended on Jun 30, 2014. Both models aim to improve hypertension management in rural China, with the integrated care model focusing on increasing the continuity of health care and adherence to medications and the financial incentive model focusing on decreasing costs of the operations.[4] Similar models have been tested in other

[4] More details of the background and the interventions can be found in Zhang et al. (2016) and Tang (2015).

countries, for example, the Accountable Care Organizations in the United States, the Integrated Care Pioneers in the U.K., and the Gesundes Kinzigtal model in Germany.

In the study, six towns were randomly assigned to three groups: two treatment groups (Group 1 and Group 2) and one control group. Group 1 only received the integrated care model, and Group 2 received both the integrated care model and the financial incentive model. The control group retained its usual care.

3.1 The Integrated Care Model

The integrated care model was implemented for both Group 1 and Group 2 in August 2012. This model had two important features. One was to combine treatment and prevention care across a multidisciplinary team, so that each patient potentially had a team of twenty-seven providers, consisting of twenty-three clinicians and four non-clinical staff. The other feature was to provide continuous care coordination across the village-town-county three-tier delivery system. All participating providers shared patient medical records, lab results, and other health related documents so that continuous care could be effectively provided to the patients. We improved the communication among doctors by setting up monthly lectures on how to diagnose and treat patients with hypertension and conducted case reviews on selected patients. County doctors would give lectures to town doctors, and town doctors to village clinicians. We also provided clear guidelines on the heath care delivery for patients with different levels of hypertension severity.

3.2 The Financial Incentives Model

A provider level financial incentives model was implemented for Group 2 in June 2013. A contract was signed with each town that clearly stated that if at the end of the performance year, the total actual inpatient spending for all patients with hypertension in Group 2 towns was above the benchmark amount, the participating providers would be paid according to the regular reimbursement schemes; however, if the total actual inpatient spending was below the predicted benchmark amount, they would obtain a bonus equal to 60% of total savings. A list of potential cost-saving methods were specified, including reducing the hospitalization rate and the length of hospital stays, especially at county seat level. The contract also set minimum quality requirements so that the providers would not sacrifice quality over cost.

During the intervention period, due to administrative issues, Qianjiang county health bureau was not able to honor the bonus that was set to be 60% of the savings. Instead, the head of the Qianjiang administrative office set the actual bonus at the end of the project at 70,000 RMB (10,654 USD) per town in Group 2, and it was paid through the research grant. However, during the intervention period, providers were not aware of this change. Since the financial incentive model only lasted for one year, rather than being repeated several years, even though the final bonus was different from what stated in the contract, the incentives from the contract remained unchanged.

3.3 Randomization

Randomization for the study was conducted first at the town level, then at the patient level.

At the town level, the head of the Department of Health in Qianjiang first identified six towns as feasible for this trial. We then divided these six towns equally into two clusters based on their population size, development level, hospital quality, and distance to the county seat, as shown in Table 1. In each cluster, we randomly assigned one of the three towns to Group 1, Group 2, and the control group. If a town was selected, all villages in the town were automatically selected for the study. Figure 2 shows the geographic location of the six towns. Because all six participating towns are within a circle of 40 kilometer (25 mile) radius and administratively belong to the same county, any differences related to location that could affect income changes, such as climate, agricultural technology, and crop price, are limited. We present more evidence in the similarity of the towns in Section 5.2.

At the patient level, we randomly selected 300 patients from each town to conduct two in-person in-house surveys. The baseline survey was conducted in June 2012 and the second survey in June 2014. We first obtained the entire list of local residents officially registered as hypertension patients in the national chronic disease database between January 2008 and January 2012.[5] The list included 5,789 patients. Then, we stratified a random sample on the basis of three criteria: gender (female and male), age (35-60, 61+), and risk level of hypertension (high, medium, and low). Using these three variables, we stratified 12 mutually exclusive subgroups per town and selected patients by subgroup.[6] Among 1,800 randomly-sampled patients, 1,408 individuals had valid baseline survey data and 1,245 of these individuals also completed the end-point interview. Excluding those who did not report their income or other necessary characteristics, we ultimately had 1077 patients in the final sample: 283 in treatment group 1, 492 in treatment group 2, and 302 in the control group. Figure 3 graphs the age distribution and the baseline blood pressure distribution for all participants. The overall study population is hypertensive patients with an average age of 66 and average base systolic blood pressure of 144.6 mmHg.

4 Measurements and Data

4.1 Measurements and Study Population

We use systolic blood pressure to measure the severity of hypertension. Although there is a distinction between systolic hypertension and diastolic hypertension, multiple studies show that systolic blood pressure identifies most of people needing treatment while there is a declining relative importance of diastolic pressure with advancing age (Kannel et al., 1971). In 2008, three hypertension experts proposed that the systolic reading to be the only blood pressure measurement used in tracking and diagnosing hypertension in population over age 50 (Williams et al., 2008). Thus, in our study, we focus on systolic blood pressure only.

[5] Having a national official medical record means that these patients were aged 35 and over, had a history of hypertension for at least six months, had blood pressure recorded at least four times a year, and had at least three measures of blood pressure greater than 140/90 mmHg.

[6] We excluded some patients before the random sampling due to accessibility issue. See Zhang et al. (2016) for details.

We obtained bimonthly blood pressure data from the national chronic condition management registry database and calculated the average blood pressure in 2012 and 2013 for each individual in our sample.

Since intervention 2 started in the middle of 2013, the effect of this intervention on 2013 income is limited. Thus, we do not distinguish treatment group 1 from treatment group 2, and refer to these two groups as the "treatment group."

The average change in blood pressure for the control group and the treatment group, along with 95% confidence intervals, are displayed in Figure 4. Subjects in the control group experienced almost no change in blood pressure, while subjects in the treatment group experienced an average blood pressure decrease of 6.19 mmHg. One common concern in the medical literature of hypertension measurement is that the office readings of blood pressure might be inaccurate, resulting in "white coat hypertension" or "masked hypertension". More specifically, white coat hypertension refers to scenarios where blood pressure is consistently elevated for office readings but not for out-of-office readings; masked hypertension refers to blood pressure being consistently elevated for out-of-office readings but not for office readings. This inaccuracy is usually caused by the pressure of being in a hospital and being treated by an unknown health care professional. In our sample, patients' blood pressure was measured repeatedly (16 times) by the same doctors, who lived in the same neighborhood, and whom the patients were familiar with. Moreover, the patients in our study had been diagnosed with hypertension at least six months earlier and had three or more measures of blood pressure greater than 140/90 mmHg in the Chinese national official medical record before our interventions began. Thus, white coat hypertension and masked hypertension were unlikely to occur in our trial.

Individuals were asked about their annual income and the change in annual income from last year in the endpoint survey, allowing us to construct income data for 2012 and 2013. One caveat is that this income includes government subsidy and pension, in addition to pure labor income. We also cannot entirely rule out remittances from their adult children who may have migrated to the city to seek jobs. However, we can partially address this concern by using the *changes* in the log of annual income as our outcome variable, since if government subsidy and pension are constant overtime, then the changes in the reported income should only be the result of changes in labor income and possibly remittances. Chongqing Civil Affairs Bureau (2008) shows that annual government subsidies and pensions were the same for all of the towns and did not change during our study period. Thus, in our main specification, we examine how the *changes* in health affect the *percentage change* in labor income. We will further show that our results are not driven by remittance or government subsidies employing placebo tests illustrated in Section 5.2. The distribution of changes in income for the overall population is graphed in Figure 5. From 2012 to 2013, individuals' average income increased by 2.73%, with around 40% of people reporting no change and about 10% experiencing more than a 10% increase or decrease.

As illustrated in Section 2.3, most rural residents in Qianjiang have labor income, but the rest are supported by their family or the government. In order to estimate the effect on those with labor income, we focus on individuals still in the labor force. We do not have any direct indicators for their labor market status, so we use two indicators as proxies derived from two survey questions. One question asks "Are you engaged in farming?" If the answer is "Yes," then the individual is labeled as "Farming" and considered to be inside the labor force. Another question asks "Is your physical ability severely impacted by diseases?" If the answer is "No," then the individual is labeled as "Not Disabled" and listed as inside the labor force. The corresponding complementary sets are labeled as "Not Farming" and "Disabled." These two groups are largely overlapping, but there are still some discrepancies. For example, those who are not engaged in farming can still be responsible for selling products on the local market, while some do not do farm work even though their physical ability allows them to. Thus we report results using both indicators. There are 735 individuals (68%) who are not disabled and 566 individuals (53%) who are engaged in farming. Of individuals who are engaged in farming, 93% are not disabled, and of those not disabled, 72% are engaged in farming. These two groups—those who are engaged in farming and those who are not disabled—w will be the focus of our study in Section 5.

Figure 6 shows the comparison of income changes for individuals inside the labor force between the treatment group and the control group. Individuals' income in the control group increased by around 2%, while the income in the treatment group increased by about 4%.

4.2 Covariates

Covariates include individual sociodemographic and health related characteristics, and town level characteristics. Sociodemographic characteristics include age, gender, family structure (living alone, with spouse, with children only, with spouse and children, or with others), number of family members in the household, and education level (no education, elementary and middle school, high school and above). Health related characteristics are salt control, fat control, use of anti-hypertension medications, hospitalizations rate, and personal medical expenditure. Town level characteristics include the number of residents in the town and the distance from the town to county seat, taken from Table 1.

Table 2 summarizes the comparison of characteristics between the treatment and control groups in the baseline. Most individual characteristics are comparable between two groups. However, individuals in the treatment group have a higher baseline blood pressure and a lower baseline log of income than those in the control group. The baseline log of income in the treatment and control groups are approximately normal distributions (Figure 7) show that the income in the treatment and control groups are approximately normal. To address the differences at the baseline, we include all the baseline values in the empirical analysis and utilize a propensity score matching (PS weighting) method.

5 Empirical Strategy

5.1 Instrumental Variables Approach

The most direct approach to estimate the effect of health on income is to run a regression of percentage change in income, $\Delta LogInc$, on the changes in blood pressure, ΔBP, controlling for individual characteristics at the baseline:

$$\Delta LogInc_i = \alpha_1 + \alpha_2 \Delta BP_i + \alpha_3 Cov_i + \alpha_4 logInc12_i + \alpha_5 BP12_i + \epsilon_i \tag{1}$$

where Cov is a vector of the covariates introduced in the last section, $logIn12$ is the baseline log of income in 2012, and $BP12$ is the baseline blood pressure in 2012. $\Delta LogInc = (logInc13 - logInc12) \times 100$, representing the percentage change in annual income.

However, using OLS regression can be problematic since health is endogenous. Thus, we used an instrumental variables strategy, of which the first stage takes the following form:

$$\Delta BP_i = \beta_1 + \beta_2 IV_i + \beta_3 X_i + \upsilon_i \tag{2}$$

where X is a vector of variables including Cov, $logInc12$, and $BP12$. The instrumental variables IV is a binary indicator, with 1 indicating the treatment group. There are 6 towns and 55 villages in our sample. Theoretically, standard errors should be clustered at the town level. However, we only have 6 towns so the number of clusters are too small (Donald and Lang, 2007). We tested the size of the standard errors using different techniques: clustered at the town level, clustered at the village level, bootstrapped, and the regular robust standard error. (See Appendix A for details.) The magnitude of the standard errors does not change much, so we choose the technique that gives us the most conservative option–clustering at the village level. If the relevance restriction and exclusion restriction are both satisfied, the instrumental variables strategy can correct the reverse causality and omitted variable biases. Thus, we can estimate the marginal causal effects of lowering blood pressure on income consistently.

For easier interpretation, we standardized the blood pressure measure. After the standardization, change in blood pressure, Δbp, had a mean of 0 and a standard deviation of 1: $\Delta bp = \frac{\Delta BP - mean(\Delta BP)}{sd(\Delta BP)}$.

Table 3 presents the first stage results with F-statistics for individuals inside the labor force under different specifications. The results show that the interventions significantly decreased blood pressure by 0.341-0.479 standard deviation for those not disabled and 0.302-0.378 standard deviation for those engaged in farming. All F-statistics are large enough to conclude a strong IV.

The exclusion restriction hinges on the assumption that the instrument is uncorrelated with the unobservable ($cov(IV, \upsilon) = 0$) and only affects patients' income through their health. Since the two interventions were randomly assigned, the instrumental variables were uncorrelated with unobservables like patients' working hours and work strenuousness. Since the interventions were imposed directly on health care providers rather than on patients, the effect on patients' income could only have come from changes in their health. Thus, the exclusion restriction is satisfied. We will address more concerns regarding the exclusion restriction and identification in Section 5.2.

We also used two different instruments, one indicating treated by intervention 1 and the other indicating treated by intervention 2. Since intervention 2 started in the middle of 2013, the effect of this intervention on 2013 income is limited. Thus we consider this approach as supplementary evidence and show the results in Appendix B. The results are qualitatively the same as our main specification using only one instrument.

5.2 Addressing Concerns of Identification

5.2.1 Differences in Income

At the baseline, individuals in the treatment group have higher annual income than those in the control group. To address the unbalanced baseline income, we utilized a propensity score method with an inverse probability of treatment weighting to balance the characteristics of individuals in each group (Rosenbaum and Rubin, 1983; Hirano and Imbens, 2001). When calculating the propensity scores, we accounted for the individual-level characteristics mentioned in Section 4.2, together with baseline income and blood pressure, using a logistic regression to estimate the probability of being in the treatment group. We then assigned a weight to each observation that is the inverse of the estimated propensity score of the individual's assignment to its group. Weightings were calculated separately for each sub-population: individuals engaged in farming, individuals not engaged in farming, not disabled individuals, and disabled individuals. After weighting, all characteristics were balanced (Table 4). We report estimation results with and without propensity score weighting in Section 6.

Another concern when there is unbalanced baseline income is "regression to the mean", i.e. those with higher baseline income might have a slower growth in the future. However, our hypothesis predicts that the treated subjects whose baseline income is higher than the control group are the ones with higher income growth, which suggests that our estimation can be considered as a lower bound.

5.2.2 Instrument Validation

Since randomization occurred at the town level, there are concerns that the income differences were driven by changes in non-labor income at group level, such as remittances or government subsidies, or some unobservable characteristics related to town-level crop output.

In order to rule out the possibility that the effect came from the changes in non-labor income, we conducted falsification tests using individuals outside the labor force—"Not Farming" and "Disabled"—as placebos. If the results were driven by income from remittances or government subsidies, we would observe similar effect among individuals both inside and outside the labor force; if not, the effect would only show up for individuals in the labor force. We report estimation results for this placebo tests in Section 6.2.

Figure 8 reports the mean changes in blood pressure with 95% confidence interval for treated individuals inside and outside the labor force respectively. Blood pressure was lowered by a similar amount, regardless of their labor force status. This suggests that if their income changes are different, it is not due to the different drops in blood pressure level.

As for the unobservable characteristics related to crop output at town level, since our outcome variable is the *changes* in income, the identification is valid as long as there are no changes in elements that affected crop harvest differently for different towns. All six participating towns are close to each other, so there are limited differences in temperature, rainfall, sun exposure and other climate characteristics. Since all six towns are in the same county, there was no difference in technology adoption and profitability of different crops as well.

To further alleviate any concerns in this matter, we include town characteristics such as population and distance to county seat in the covariates to control for any differences among towns.

5.2.3 Health Measurement

Another concern is that the results might not come directly from hypertension, but from some mental effect or other health improvement induced by the interventions. For example, getting more attention from the doctors might increase the happiness and productivity of the patients. We used RAND's Medical Outcome Study Short-Form 36-Item Health Survey (SF36) as a comprehensive subjective health measure to rule out these possibilities.[7]

The SF36 score relies upon patient self-reporting on 36 questions and it is widely used

[7] For more details, see RAND website on SF36 Survey.

by heathcare organizations for routine monitoring and assessment of care outcomes in adult patients. For easier interpretation, we scale all the scores to be between 0 and 100. The larger the number, the healthier the individual feels. We used the total summary score (SF36 score), and the results were qualitatively the same when using more detailed indicators.

The SF36 score for each individual was obtained from the two surveys. The mean values of changes in SF36 score for individuals engaged in farming and not disabled individuals are displayed in Figure 9 with their 95% confidence intervals. Subjects in the control group show almost no change in SF36 score, while on average there is a 0.23 standard deviation increase for the treatment group.

In order to verify that the improvement in income was caused by decreases in blood pressure instead of changes to other health characteristics, we include ΔSF—the change in SF36 score between 2012 and 2013—in the covariates and re-run the model illustrated by Equations (1) and (2). If the improvement in income is indeed due to hypertension control, including ΔSF would render no difference to our main results. We report the estimation results in Section 6.3.

5.2.4 Selection

Since the interventions are directly imposed on the delivery system and health care providers and not patients themselves, there is a potential patient selection problem. However, even though residents in these six towns have the freedom to choose their providers, they almost always go to the clinics or infirmary in their own towns because of convenience. We checked the inpatient records between 2008 and 2014, finding that only 0.8% (44 out of 5,116 cases) of town level hospital stays involved patients attending hospitals located in a different town. Thus the hospital selection problem and unintended treatment are trivial.

5.3 Income Improvement Channels

To further verify the second stage of the instrumental variables approach, we clarify the channels through which hypertension affects income. Since we only examine income changes over a short period of time (two years), farmers cannot improve their earnings by switching to crops that are more profitable. Thus there are only two ways for the farmers to actively increase their income: improve labor productivity or elongate working hours. Better health can potentially lead to both.

We used several indexes to measure the influence of physical well-being on different aspects of work. We have an overall index that is derived from the question "Did your physical pain negatively affect your work or housework in the past month?" It takes on values between 1 and 5, with 1 corresponding to the largest impact and with 5 being no impact. We created three other binary variables, one for labor hours based on the answer to the question "Did you decrease labor hours due to health reasons in the past month?", and two for labor productivity indicators based on answers to these questions: "Did you feel that you can only complete part of the daily task you planned due to health reasons in the past month?" and "Did you feel it is more difficult to work due to health reasons in the past month?" We then calculated the changes in these variables before and after the interventions and used them as outcome variables. Changes in the overall index ranged between -4 and 4, with a smaller number indicating higher negative impact on work due to physical pain post v.s. pre interventions. Changes in hours and productivity variables have values of -1, 0, and 1, with 1 indicating improved labor productivity or longer hours post interventions, -1 indicating reduced productivity or decreased hours, and 0 indicating no changes.

We ran the following regressions to examine whether productivity and time were affected by blood pressure level:

$$\Delta Index_i = \lambda_1 + \lambda_2 \Delta bp_i + \lambda_3 Cov_i + \lambda_4 Index12_i + \varsigma_i \tag{3}$$

where $\Delta Index$ is the changes post and pre interventions in one of the four indexes, $Index12$ is the baseline index level, and Cov is the vector of covariates introduced in Section 4. If λ_2 is negative, it suggests that lower blood pressure is accompanied by smaller impact from physical pain, higher productivity, or longer working time. We conducted this analysis respectively for individuals engaged in farming, individuals who were not disabled, and the overall population.

6 Results and Cost-Benefit Analysis

6.1 Instrumental Variable Results

Table 5 reports the effect of changes in health on percentage changes in income for those who are not disabled. We explored different specifications and showed results both with or without PS weighting. Column (1) in the table presents estimations from an OLS regression and columns (2)-(5) the results from instrumental variables approaches. In the OLS regression, changes in systolic blood pressure level show a very small correlation with income: a one standard deviation decrease in blood pressure is related to about 1% increase in income, the equivalent of 68 RMB. After instrumenting blood pressure level, the magnitude of the effects greatly increases. For not disabled individuals, a one standard deviation decrease in blood pressure now increases income by 5.21%-5.51% without propensity score weighting (upper panel column (2)-column (5)). After balancing the baseline characteristics with propensity score weighting, the magnitude of the coefficients slightly decreases but is still very sizable: a one standard deviation decrease in blood pressure increases income by 4.20%-5.06%(lower panel column (2)-column (5)). This effect is robust under different specifications, indicating that town level differences at the baseline are not driving the results. The increase in the magnitude of the coefficient is most likely due to the omitted variable in the OLS regression, such as work strenuousness that increases income and deteriorates health at the same time.

Table 6 shows similar patterns for those who are engaged in farming. Simple correlation between health changes and percentage changes in income is small (1%) but the causal effect is large: a one standard deviation decrease in blood pressure increases income by 9.26%-10.29% without propensity score weighting and 7.17%-8.91% with propensity score weighting. Comparing Table 6 with Table 5, the effect is much larger for those engaged in farming than those who are not disabled. Since physical ability is most important for those engaged in farming, it is not surprising that an improvement in health benefits them the most.

The instrumental variables results reported here were calculated using a Two-Stage-Least-Square (2SLS) estimator. We also used a Limited Information Maximum Likelihood (LIML) estimator instead of the 2SLS estimator, following Imbens (2014), and the results are virtually the same.

6.2 Placebo Test Results

To verify our identification strategy, we conduct placebo tests using individuals outside the labor force and report. Results are reported in Table 7 and Table 8. For those whose physical abilities are severely impacted by disease (Table 7) or individuals not engaged in farming (Table 8), the coefficient estimations are all positive and insignificant, suggesting that their income stayed unchanged even though their blood pressure level dropped at a rate similar to those inside the labor force. Thus, hypertension control only improves labor income, relieving our concern that government subsidies and remittances might have confounded the results.

6.3 Subjective Measure SF36 as a Supplement

To rule out the possibility that the changes in income are driven by other changes brought by the interventions, instead of hypertension, we use the SF36 score as a self-assessed measure for overall health. We first include it in the covariates and report the results in Table 9. Including the SF36 score renders almost no change to our main results in Table 5 and Table 6. With PS weighting, a one standard deviation decrease in blood pressure at least increases income for not disabled individuals by 4.286% (upper panel column (4)) and individuals engaged in farming by 7.042% (lower panel column (4)), which is very similar to the 4.201% and 7.172% without the inclusion of changes in the SF36 score. The coefficients for the changes in SF36 score are insignificant, suggesting that all of the effects are represented by blood pressure level.

6.4 Income Improvement Channels

At last, we verified the second stage of the instrumental variables regressions by examining whether health affects income through labor productivity or time. Results are reported in Table 10. Overall, with the decrease in blood pressure level, individuals in our study reported less negative impact on their work due to physical pain. When we examine the effect on labor productivity indexes and time index, we find that a lower blood pressure is significantly related with an increased labor productivity, but the relationship between health and labor time is not significant. These links are robust among individuals who are engaged in farming, individuals who are not disabled, and the overall population. Consistent with Tables 5 and 6, those engaged in farming are the most affected since physical ability is most important for them. This suggests that improving hypertension mainly improve earnings through increased labor productivity instead of elongated working hours.

6.5 Cost-Benefit Analysis

We conducted a cost-benefit analysis to assess whether these health interventions can result in welfare gains. In particular, we calculated and compared the cost of conducting the trial with the income improvement induced by the interventions.

There are four costs related to the interventions: labor costs, operational expenditures, the financial bonus, and gifts provided to survey participants. First, labor costs for extra work from health care providers in the study is an estimated 644.36 extra hours per month for all of the participating towns. The health care providers were not actually paid for these extra hours in the trial, so they have no financial incentive to exaggerate a reported number. We assigned a 21 RMB hourly wage rate in this exercise to calculate the corresponding labor cost.[8] The total cost associated with extra labor hours is thus 162,378 RMB a year ($644.36 \times 21 \times 12$ RMB). Second, the main operational expenditures were around 19,004 RMB per year. This includes costs related to staff training and group learning; printing documents for health education, health records and information transfer; and accommodation and transportation for group meetings and on-site visits. Third, the total bonus paid to the providers in Group 2 was 140,000 RMB. Even though intervention 2 started in June 2013 hence its effect on income in 2013 should be limited, we still included this cost in order to be conservative for the welfare gain estimation. Fourth, in order to increase the response rate of the in-house survey, we asked the village clinicians who know patients well to accompany the interviewers to patient homes, and we provided some gifts such as toothpaste and soap. The value of the gifts was about 16,000 RMB. In sum, the total cost of these two interventions was 337,383 RMB per year.

When calculating the gain from the interventions, we pick the most conservative results so that our estimations are the lower-bound. Table 5 suggests that for not disabled individuals, one standard deviation decrease in blood pressure (9.50 mmHg) at least increases income by 4.20%, an equivalent of 287.94 RMB. Table 6 suggests that for those engaged in farming, one standard deviation decrease in blood pressure (9.54 mmHg) at least increases income by 7.17%, an equivalent of 490.42 RMB. On average, the blood pressure for individuals in the treatment group was lowered by 6.58 mmHg for those not disabled and 6.44 mmHg for those engaged in farming. Thus the per capita annual increase in income induced by blood pressure improvement is 199.44 RMB ($287.94 \times \frac{6.58}{9.50}$) for those not disabled or 331.06 RMB ($490.42 \times \frac{6.44}{9.54}$) for those engaged in farming. There were 4,193 hypertensive patients

[8] We use the average annual salary in Chongqing in 2012 as the standard to calculate the hourly wage, and assume that people work 52 weeks a year, 5 days a week and 8 hours a day. The result is 21.82 RMB/hour. Since rural area usually has a lower hourly wage than the equivalent number calculated from annual salary, this gives us an upper bound for the actual hourly wage. Also note that the minimum hourly wage in Qianjiang in 2012 is 10.5 RMB/hour (Chongqing Human Resource Bureau, 2012), so our number is twice the value.

treated in our trial in the 4 towns. Assuming that the percentage of individuals inside the labor force in the randomized samples are the representative of all the treated 4,193 hypertensive patients, then individuals who are not disabled and individuals engaged in farming consist of 68% and 53% of the treated patients, respectively. The improved income is then estimated to be 579,698 RMB ($199.44 \times 4193 \times 68\%$) for those not disabled, or 729,511 RMB ($331.06 \times 4193 \times 53\%$) for those engaged in farming. The most conservative estimation of benefit from improved income is almost twice the size of the cost. If we take into consideration the benefit from improved physical well-being, the welfare gains could be even more substantial.

In summary, the health interventions that we conducted to lower blood pressure resulted in sizable welfare gain, even in the short run. In the long term, we expect this gain to be larger.

7 Conclusion and Discussion

In this paper, we examined the effect of hypertension control on income in rural China by taking advantage of a dataset collected from a randomized controlled trial designed to improve hypertension management. Our study participants are mainly self-employed farmers, whose physical conditions affect their labor income substantially, which allows us to observe the impact of decreasing blood pressure in the short run.

We found that a one standard deviation decrease in systolic blood pressure can significantly increase annual income by 7.17% for individuals engaged in farming and 4.20% for individuals who are not disabled. We examined the channels through which health can affect income and found that the increase in income came from an improvement in labor productivity rather than an elongation of working hours. Cost-benefit analysis shows that the gain from improved income is much larger than the cost of the interventions, suggesting that our interventions to improve hypertension resulted in substantial welfare gains.

There have been rising interests in the literature on the relationship between labor market outcomes and chronic diseases, such as diabetes and depression. In general, there is a lack of research on labor market impact of all prevalent chronic diseases in low or middle income countries. To our knowledge, this paper is the first to examine the link between hypertension and income. With respect to type 2 diabetes, a literature review shows that studies on high-income countries generally find a considerable negative impact of diabetes on employment choices and income, but the economic burden associated with diabetes in developing countries is less clear (Seuring et al., 2015). In the only paper that focuses on China in this area, Liu and Zhu (2014) find that diabetes leads to an average 16.3% decrease in income after people are diagnosed. Depression is another chronic disease that has gained much attention in the economics literature. Kessler et al. (1999) suggest that treating workers' depression can help employers to save money on disability. Both Chatterji et al. (2011) and Peng et al. (2015) find that depression is associated with reductions in labor force participation and employment, but has no effect on hourly wage, most likely due to the prevalence of employment contracts (Chatterji et al., 2011; Peng et al., 2015).

Our results are encouraging and they fill the gaps in the literature on the labor market effects of chronic diseases in the developing countries, but it is not without limitations. One major concern is that the randomization was at the town level, so the results might not have been caused by lowered blood pressure but some other characteristics that varied at the town level. We alleviate this concern by noting the similarities among the six towns in agriculture technology, crop composition, and climate, and conducting placebo tests using individuals outside the labor force. Another limitation is that the findings might not be able to be extrapolated to a richer, younger, or more urban population. Our interventions were conducted in a rural county in China, where labor costs were low and hypertension management was poor. The study subjects are hypertensive farmers with an average age of 65 years old, with very different income structures compared to the urban residents. The hypertension management is more advanced in urban areas, which renders lower marginal return, while the expense of conducting similar interventions can be larger in urban areas, resulting in higher marginal cost.

However, our results can be applied to similar rural populations in other developing countries in South Asia, Africa, and South America, especially for countries where the burden of chronic conditions, including hypertension and other cardiovascular diseases, is rapidly increasing. China, the most populous country in the world and a country facing the problem of an aging population, contains 18% of the world's population. As of 2014, there are 618.7 million rural residents and 137.6 million people above 65 years old. Thus, even without extrapolating, our paper helps inform a policy discussion that is deeply important to a large segment of the world's population.

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Figure 1: Location of Chongqing City and Qianjiang County

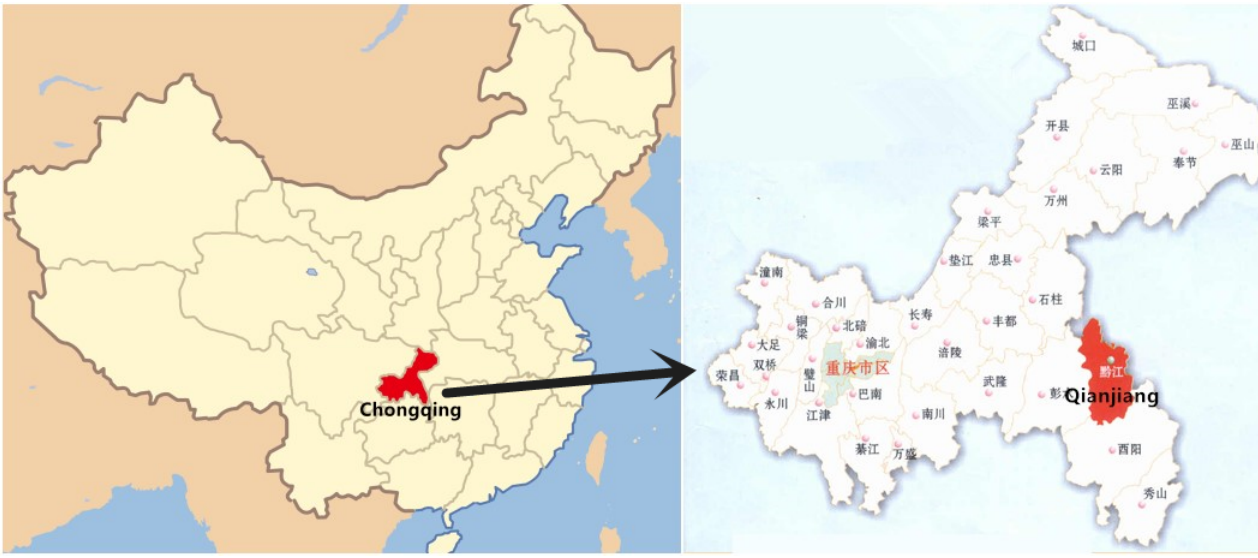
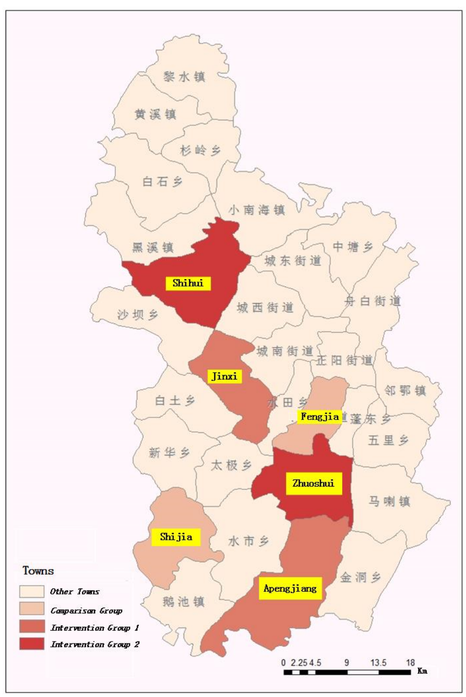
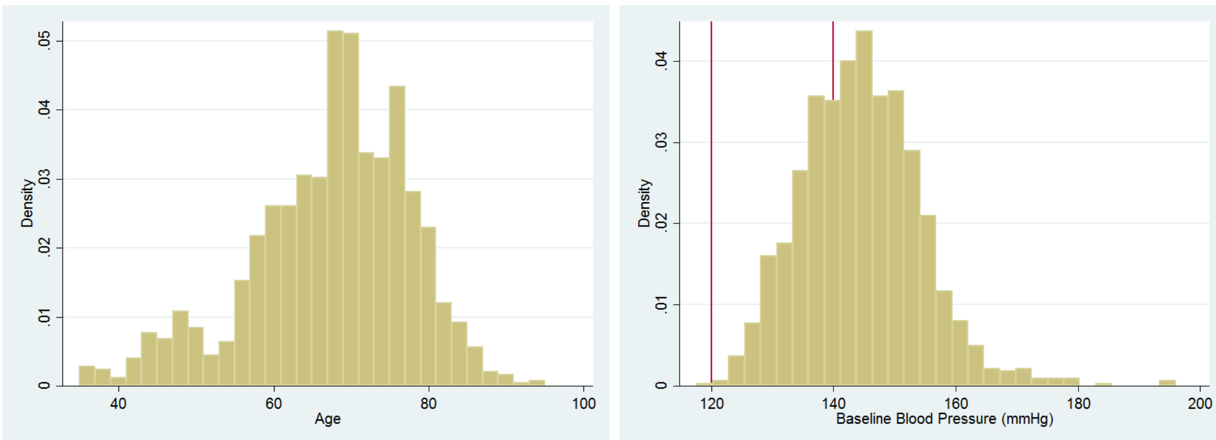


Figure 2: Geographic Location of the Six Towns



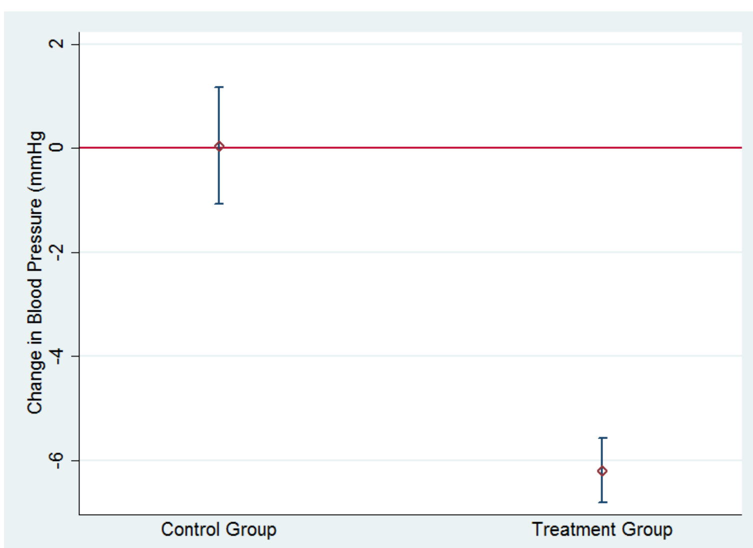
Notes: Treatment Group 1 consists of Jinxi and Apengjiang, treatment Group 2 consists of Zhuoshui and Shihui, and control group consists of Shijia and Fengjia. This figure is the same as Figure 1 in Zhang et al. (2016).

Figure 3: Sample Characteristics: Senior Hypertensive Patients



Note: Our study population is hypertensive patients with an average age of 66 and average base systolic blood pressure of 144.6 mmHg.

Figure 4: Changes in Blood Pressure with 95% CI



Note: Subjects in the treatment group are those exposed to intervention 1 or intervention 2. Normal systolic blood pressure should be below 120 mmHg and having a systolic blood pressure above 140 mmHg is defined as hypertension.

Figure 5: Distribution in the Percentage Change in Income

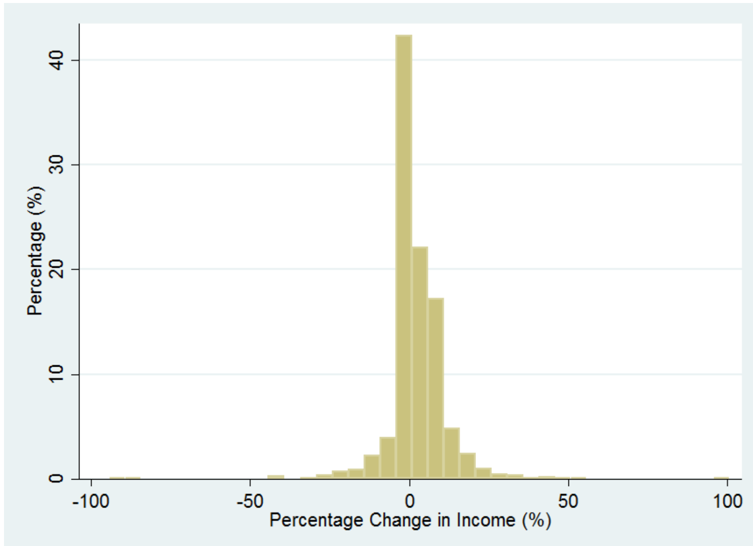
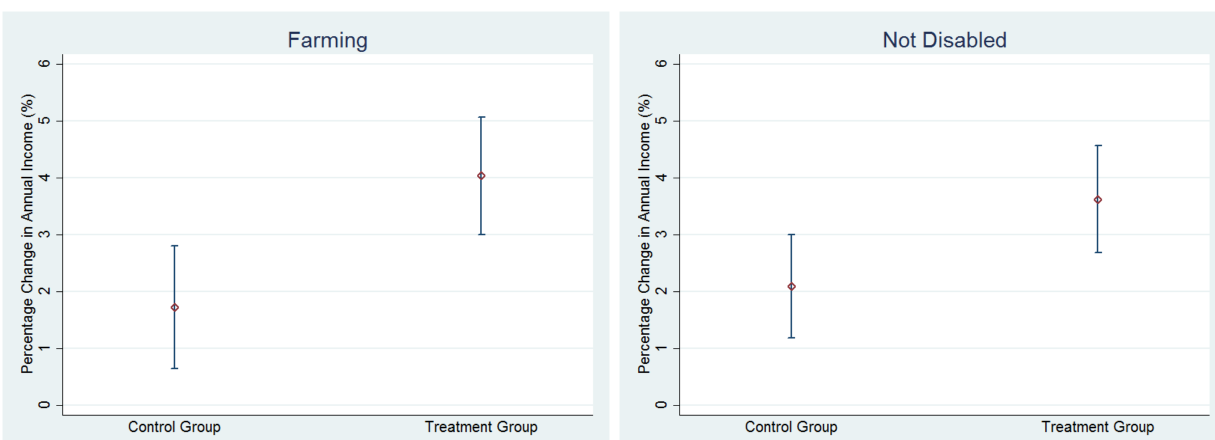


Figure 6: Percentage Change in Income with 95% CI



Note: Subjects in the treatment group are those exposed to intervention 1 or intervention 2. The left plot shows the percentage change in income for individulas engaged in farming and the right plot shows the number for those who are not disabled. In both cases, individuals in the treatment group have a larger growth in income.

Figure 7: Kernel Distribution for Income in the Treatment and Control Group

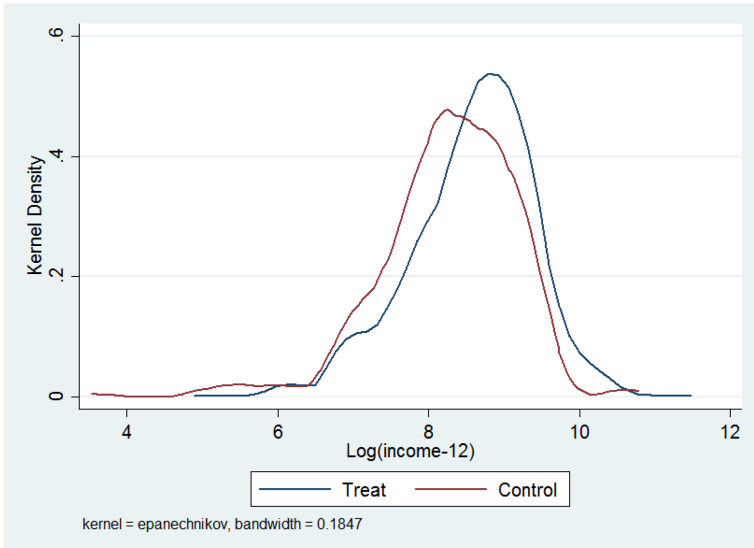
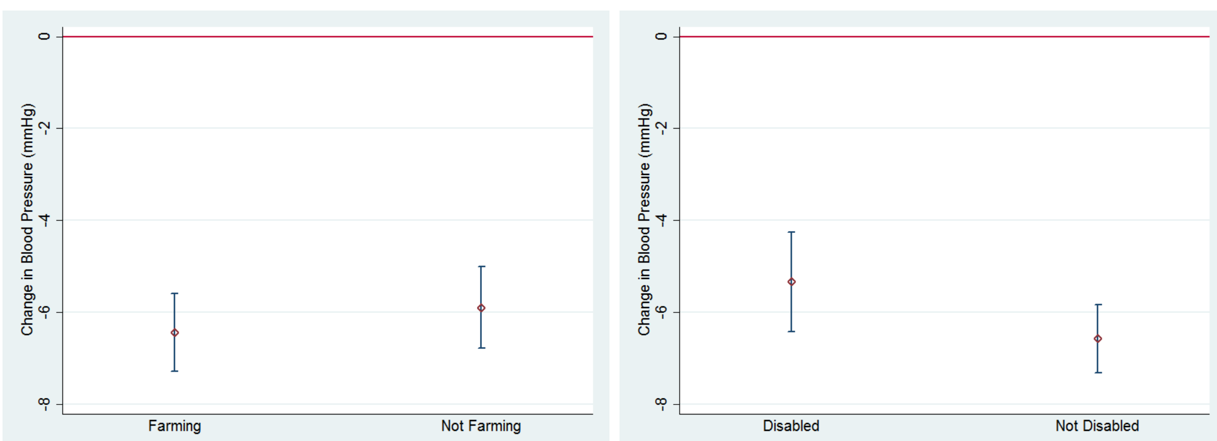
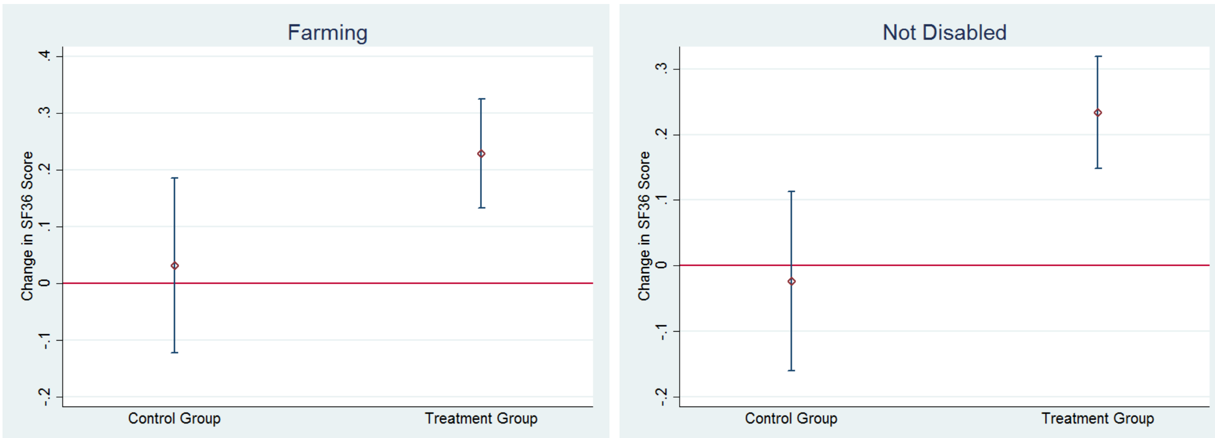


Figure 8: Changes in Blood Pressure in the Treatment Group with 95% CI



Note: This figure shows the changes in blood pressure level in the treatment group for those inside and outside the labor force, respectively. The left plot distinguishes individuals' labor market status by asking whether they are engaged in farming or not, and the right plot by whether they are disabled or not.

Figure 9: Changes in SF36 Scores with 95% CI



Note: Subjects in the treatment group are those exposed to intervention 1 or intervention 2. The left plot shows the change in SF36 score for individulas engaged in farming and the right plot shows the number for those who are not disabled.

Table 1: Characteristics Used to Randomly Assign Six Towns to Three Groups

	Group 1		**Group 2**		**Control**	
	Apengjiang	Jinxi	Zhoushui	Shihui	Fengjia	Shijia
Number of residents	28,000	15,600	27,055	22,448	27,464	14,126
Annual income per capita (RMB)	6452	5417	6487	5452	6900	5031
Distance to county seat (minutes)	50	90	30	60	25	100
Medical revenue (10,000 RMB)	265	169	279	198	311	159

Notes: These basic characteristics were surveyed in July 2012 and used to randomly assign towns to the three groups. We first divided the six towns equally into two clusters: one cluster of three towns with a smaller population, lower socioeconomic development levels, poorer hospital quality, and further distance away from the county seat (Jinxi, Shihui, and Shijia); and the other cluster with contrasting characteristics. In each cluster, we randomly assigned three towns to Groups 1, 2 and the control group, respectively. This table is the same as Table 1 in Zhang et al. (2016).

Table 2: Summary Statistics: Comparison of Characteristics at the Baseline

	mean(Control)	mean(Treat)	Difference	s.e.
Age	66.07	66.68	-0.61	0.72
Female ratio (%)	55.63	53.68	1.95	3.38
Living alone (%)	14.57	15.87	-1.30	2.46
Living with spouse (%)	36.09	32.90	3.19	3.21
Living with kids (%)	17.22	15.87	1.35	2.50
Living with spouse and kids (%)	30.13	33.81	-3.67	3.19
Household size	3.51	3.66	-0.15	0.15
Attended elementary school (%)	46.69	53.42	-6.73*	3.39
Attended high school or above (%)	17.22	17.16	0.06	2.56
Salt control	3.22	3.42	-0.21*	0.10
Fat control	3.47	3.59	-0.11	0.10
Use of anti-hypertension medication (%)	35.10	36.13	-1.03	3.26
Hospitalization rate (%)	18.54	19.48	-0.94	2.68
Personal medical expenditure (RMB)	2552.96	2359.76	193.19	482.50
Average income in 2012 (RMB)	5404.57	7129.69	-1725.12***	394.88
Baseline blood pressure (mmHg)	141.05	146.11	-5.06***	0.65

Notes: Salt control and fat control: 1=never 2=occasional 3=sometimes 4=often 5=always. Significance level in t-test: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: First Stage Results

	(1)	(2)	(3)	(4)	(5)	(6)
Sample: Not Disabled						
IV	-0.341***	-0.429***	-0.443***	-0.387***	-0.465***	-0.479***
	(0.128)	(0.129)	(0.127)	(0.120)	(0.119)	(0.115)
Age	-0.00117	-0.00233	-0.000613	-0.00302	-0.00408	-0.00274
	(0.00419)	(0.00402)	(0.00402)	(0.00460)	(0.00450)	(0.00450)
Female ratio	-0.000673	-0.000871	-0.000950	-0.000575	-0.000717	-0.000764
	(0.000797)	(0.000744)	(0.000775)	(0.000903)	(0.000858)	(0.000877)
Log(income-12)	-0.0311	-0.0195	-0.0320	-0.0179	-0.00581	-0.0167
	(0.0352)	(0.0348)	(0.0345)	(0.0382)	(0.0402)	(0.0399)
Baseline Blood Pressure	-0.0573***	-0.0598***	-0.0596***	-0.0550***	-0.0576***	-0.0571***
	(0.00378)	(0.00341)	(0.00337)	(0.00310)	(0.00267)	(0.00276)
First stage F-stats	26.35	31.77	35.71	55.49	59.89	59.49
Observations	735	735	708	735	735	708
Include Health Variables	No	No	Yes	No	No	Yes
Include Town Variables	No	Yes	Yes	No	Yes	Yes
PS Weighting	No	No	No	Yes	Yes	Yes
Sample: Farming						
IV	-0.302*	-0.354**	-0.359**	-0.324**	-0.365**	-0.378**
	(0.155)	(0.152)	(0.150)	(0.160)	(0.148)	(0.145)
Age	0.000137	-0.00208	-0.00172	0.000314	-0.00320	-0.00389
	(0.00484)	(0.00454)	(0.00460)	(0.00776)	(0.00727)	(0.00762)
Female ratio	-0.000497	-0.000676	-0.000997	-6.53e-05	-6.41e-05	-0.000245
	(0.000748)	(0.000727)	(0.000757)	(0.00116)	(0.00111)	(0.00112)
Log(income-12)	-0.00679	0.0159	0.00378	-0.00338	0.0140	0.00266
	(0.0502)	(0.0480)	(0.0482)	(0.0556)	(0.0554)	(0.0493)
Baseline Blood Pressure	-0.0598***	-0.0619***	-0.0624***	-0.0620***	-0.0653***	-0.0658***
	(0.00453)	(0.00428)	(0.00447)	(0.00484)	(0.00452)	(0.00469)
First stage F-stats	22.08	22.81	25.11	21.01	21.86	23.22
Observations	566	566	541	566	566	541
Include Health Variables	No	No	Yes	No	No	Yes
Include Town Variables	No	Yes	Yes	No	Yes	Yes
PS Weighting	No	No	No	Yes	Yes	Yes

Notes: This table reports the first stage results for the IV regressions. All regressions include basic individual characteristics. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. Robust standard errors are clustered at village level. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Comparative Statistics after Propensity Score Weighting

	Farming			Not Disabled			Not Farming			Disabled		
	Control	Treat	p-value	Control	Treat	p-value	Control	Treat	p-value	Control	Treat	p-value
Age	63.80	63.57	0.84	63.40	64.70	0.43	66.65	69.51	0.22	70.19	70.06	0.92
Female ratio	48.87	53.17	0.44	55.04	53.40	0.77	62.26	55.38	0.29	59.67	55.16	0.54
Live alone	12.24	11.90	0.92	12.89	13.82	0.76	20.20	20.01	0.97	29.44	20.02	0.28
Live with spouse	35.56	35.64	0.99	33.39	35.85	0.61	29.66	33.24	0.52	31.73	32.27	0.94
Live with kids	12.19	12.40	0.95	19.25	13.24	0.39	23.82	19.47	0.61	16.26	21.05	0.31
Live with spouse & kids	38.64	38.58	0.99	33.20	35.64	0.63	25.09	25.56	0.93	21.35	24.67	0.56
Attended grade school	60.24	58.19	0.69	59.03	56.22	0.60	46.67	44.60	0.79	36.73	41.71	0.48
Attended high school	20.23	20.85	0.88	17.64	19.61	0.57	10.61	13.12	0.48	9.57	12.47	0.53
Family size	3.62	3.72	0.67	3.89	3.75	0.64	3.64	3.49	0.70	3.25	3.40	0.65
Medical expenditure	1689	2082	0.37	2777	2415	0.65	3342	2741	0.43	3210	3015	0.87
Medicine usage	42.09	38.23	0.49	36.33	37.15	0.88	34.06	34.71	0.92	41.00	33.05	0.33
Salt control	3.22	3.26	0.81	3.30	3.34	0.76	3.51	3.52	0.94	3.53	3.47	0.72
Fat control	3.46	3.49	0.88	3.64	3.56	0.66	3.79	3.64	0.43	3.53	3.51	0.95
Inpatient rate	17.58	18.37	0.83	17.02	19.14	0.55	17.83	20.41	0.58	18.62	19.13	0.93
Average income in 2012	6943	6465	0.68	6834	6602	0.82	7124	6954	0.92	5240	6852	0.01
Baseline Blood Pressure	144.60	144.84	0.83	148.59	145.21	0.38	149.57	144.83	0.33	145.52	143.97	0.63

Notes: This table show the comparative statistics after propensity score weighting. Weightings are calculated separately for each group: individuals engaged in farming, individuals not engaged in farming, not disabled individuals, and disabled individuals. Individuals in the treatment groups are those exposed to the interventions. Significance level in t-test: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Effect of Health on Percentage Change in Income: Not Disabled

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Without PS Weighting					
Change in blood pressure	-1.011**	-5.344*	-5.513**	-5.209*	-5.424**
	(0.394)	(2.931)	(2.781)	(2.700)	(2.628)
Age	0.0288	0.00754	0.00408	0.0292	0.0264
	(0.0499)	(0.0485)	(0.0488)	(0.0498)	(0.0501)
Female ratio	0.00468	0.00192	0.00132	0.00168	0.000940
	(0.00540)	(0.00608)	(0.00632)	(0.00641)	(0.00669)
Log(income-12)	-0.508	-0.617	-0.527	-0.801	-0.726
	(0.689)	(0.729)	(0.675)	(0.776)	(0.729)
Baseline Blood Pressure	-0.117**	-0.392**	-0.402**	-0.378**	-0.391**
	(0.0543)	(0.196)	(0.186)	(0.181)	(0.175)
With PS Weighting					
Change in blood pressure	-1.096***	-4.479**	-5.064**	-4.201**	-4.812**
	(0.345)	(1.996)	(2.294)	(1.906)	(2.208)
Age	0.0291	-0.00133	-0.00475	0.0190	0.0170
	(0.0488)	(0.0474)	(0.0481)	(0.0481)	(0.0489)
Female ratio	0.00358	0.00120	0.000704	0.00145	0.000752
	(0.00551)	(0.00622)	(0.00654)	(0.00635)	(0.00675)
Log(income-12)	-0.475	-0.480	-0.384	-0.602	-0.526
	(0.724)	(0.705)	(0.662)	(0.759)	(0.723)
Baseline Blood Pressure	-0.159***	-0.344***	-0.380***	-0.327***	-0.362***
	(0.0441)	(0.123)	(0.141)	(0.115)	(0.133)
Observations	708	735	735	708	708
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes

Notes: This table reports the effect of lowering blood pressure on percentage change in annual income (%) for individuals who are not disabled. All regressions include basic individual characteristics. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. Robust standard errors are clustered at village level. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 6: Effect of Health on Percentage Change in Income: Farming

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Without PS Weighting					
Change in blood pressure	-1.093**	-9.592*	-10.12**	-9.264*	-10.29**
	(0.422)	(5.151)	(4.963)	(4.889)	(4.904)
Age	0.0170	0.0139	-0.00395	0.0202	0.00396
	(0.0594)	(0.0627)	(0.0639)	(0.0650)	(0.0686)
Female ratio	0.00573	0.00342	0.00202	-0.000420	-0.00280
	(0.00868)	(0.0116)	(0.0122)	(0.0124)	(0.0137)
Log(income-12)	-0.689	-0.716	-0.380	-1.108	-0.771
	(0.774)	(0.892)	(0.834)	(0.945)	(0.912)
Baseline Blood Pressure	-0.113*	-0.666*	-0.704**	-0.641*	-0.707**
	(0.0660)	(0.342)	(0.331)	(0.330)	(0.330)
With PS Weighting					
Change in blood pressure	-1.312***	-7.485*	-8.873**	-7.172**	-8.915**
	(0.394)	(3.823)	(4.286)	(3.642)	(4.023)
Age	0.0146	0.0126	-0.0154	0.0101	-0.0167
	(0.0537)	(0.0665)	(0.0715)	(0.0656)	(0.0764)
Female ratio	0.00359	0.00417	0.00455	0.00190	0.00124
	(0.00887)	(0.0127)	(0.0134)	(0.0128)	(0.0140)
Log(income-12)	-0.388	-0.319	-0.0879	-0.546	-0.315
	(0.753)	(0.710)	(0.705)	(0.772)	(0.782)
Baseline Blood Pressure	-0.125*	-0.520**	-0.624**	-0.498*	-0.620**
	(0.0670)	(0.264)	(0.294)	(0.262)	(0.279)
Observations	541	566	566	541	541
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes

Notes: This table reports the effect of lowering blood pressure on percentage change in annual income (%) for individuals engaged in farming. All regressions include basic individual characteristics. “Health variables” include salt control, fat control, anti-hypertension drug usage, and inpatient records. “Town variables” include the number of residents in the town and the distance from the town to county seat. Robust standard errors are clustered at village level. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 7: Placebo Tests: Disabled

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Without PS Weighting					
Change in blood pressure	-0.562	1.641	2.683	2.113	2.564
	(0.458)	(3.249)	(3.585)	(3.355)	(3.444)
Age	0.0527	0.0511	0.0546	0.0384	0.0431
	(0.0386)	(0.0433)	(0.0430)	(0.0404)	(0.0386)
Female ratio	0.0126	0.0147*	0.0153*	0.0129	0.0141
	(0.00962)	(0.00820)	(0.00863)	(0.00879)	(0.00929)
Log(income-12)	-0.541	-0.0402	-0.495	-0.0554	-0.440
	(0.529)	(0.555)	(0.517)	(0.577)	(0.516)
Baseline Blood Pressure	-0.158***	-0.0201	0.0348	-0.00109	0.0247
	(0.0449)	(0.196)	(0.214)	(0.199)	(0.205)
With PS Weighting					
Change in blood pressure	-0.534	1.276	2.799	1.310	2.351
	(0.548)	(2.925)	(3.480)	(2.797)	(3.333)
Age	0.0778	0.0834*	0.0770*	0.0633	0.0597
	(0.0475)	(0.0450)	(0.0443)	(0.0437)	(0.0445)
Female ratio	0.0126	0.0146	0.0147	0.0120	0.0129
	(0.0115)	(0.0107)	(0.0112)	(0.0105)	(0.0110)
Log(income-12)	-0.424	0.0864	-0.507	0.0716	-0.447
	(0.731)	(0.795)	(0.749)	(0.754)	(0.704)
Baseline Blood Pressure	-0.157***	-0.0700	0.0373	-0.0727	0.00426
	(0.0417)	(0.178)	(0.213)	(0.168)	(0.200)
Observations	331	342	342	331	331
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes

Notes: This table reports the placebo tests using individuals who are disabled. All regressions include basic individual characteristics. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. Robust standard errors are clustered at village level. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Placebo Tests: Not Farming

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Without PS Weighting					
Change in blood pressure	-0.666	1.808	2.737	1.780	2.552
	(0.407)	(3.025)	(3.530)	(2.832)	(3.287)
Age	0.0552	0.0517	0.0561	0.0481	0.0516
	(0.0410)	(0.0474)	(0.0477)	(0.0370)	(0.0377)
Female ratio	0.00875	0.00892	0.0111	0.00764	0.0102
	(0.0109)	(0.00985)	(0.0110)	(0.0101)	(0.0114)
Log(income-12)	-0.359	0.0720	-0.206	0.105	-0.161
	(0.520)	(0.756)	(0.597)	(0.811)	(0.646)
Baseline Blood Pressure	-0.146***	0.00988	0.0552	0.00267	0.0388
	(0.0491)	(0.181)	(0.204)	(0.163)	(0.183)
With PS Weighting					
Change in blood pressure	-0.404	1.830	2.848	1.855	2.762
	(0.428)	(2.384)	(3.330)	(2.147)	(3.040)
Age	0.0552	0.0498	0.0583	0.0509	0.0541
	(0.0400)	(0.0494)	(0.0497)	(0.0373)	(0.0366)
Female ratio	0.0114	0.0123	0.0146	0.0118	0.0147
	(0.0107)	(0.0103)	(0.0123)	(0.0106)	(0.0126)
Log(income-12)	0.109	0.366	0.0557	0.367	0.102
	(0.502)	(0.596)	(0.459)	(0.625)	(0.496)
Baseline Blood Pressure	-0.117***	-0.0150	0.0581	-0.0172	0.0489
	(0.0404)	(0.137)	(0.193)	(0.119)	(0.172)
Observations	498	511	511	498	498
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes

Notes: This table reports the placebo tests using individuals not engaged in farming. All regressions include basic individual characteristics. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. Robust standard errors are clustered at village level. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9: Subjective Measure as Supplement: Including $\Delta SF36$ as a Covariate

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Sample: Not Disabled					
Change in blood pressure	-1.069***	-4.535**	-5.068**	-4.286**	-4.824**
	(0.349)	(1.915)	(2.283)	(1.820)	(2.188)
Change in SF36 score	-0.326	-0.105	-0.0619	-0.146	-0.0934
	(0.391)	(0.394)	(0.435)	(0.397)	(0.430)
Age	0.0243	-0.00266	-0.00552	0.0168	0.0155
	(0.0484)	(0.0469)	(0.0475)	(0.0472)	(0.0479)
Female ratio	0.00328	0.00106	0.000628	0.00129	0.000654
	(0.00555)	(0.00630)	(0.00657)	(0.00644)	(0.00677)
Log(income-12)	-0.487	-0.485	-0.387	-0.608	-0.529
	(0.728)	(0.706)	(0.665)	(0.761)	(0.725)
Baseline Blood Pressure	-0.155***	-0.346***	-0.380***	-0.329***	-0.362***
	(0.0450)	(0.121)	(0.142)	(0.112)	(0.133)
Observations	708	735	735	708	708
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes
Sample: Farming					
Change in blood pressure	-1.304***	-7.384**	-8.842**	-7.042**	-8.849**
	(0.402)	(3.683)	(4.223)	(3.480)	(3.918)
Change in SF36 score	-0.120	0.254	0.295	0.267	0.350
	(0.542)	(0.637)	(0.742)	(0.644)	(0.757)
Age	0.0126	0.0153	-0.0117	0.0144	-0.0105
	(0.0530)	(0.0647)	(0.0674)	(0.0626)	(0.0696)
Female ratio	0.00336	0.00471	0.00518	0.00243	0.00194
	(0.00889)	(0.0126)	(0.0134)	(0.0127)	(0.0139)
Log(income-12)	-0.395	-0.302	-0.0681	-0.530	-0.296
	(0.757)	(0.704)	(0.713)	(0.767)	(0.791)
Baseline Blood Pressure	-0.123*	-0.516**	-0.624**	-0.492*	-0.618**
	(0.0671)	(0.258)	(0.293)	(0.254)	(0.274)
Observations	541	566	566	541	541
Include Health Variables	Yes	No	No	Yes	Yes
Include Town Variables	Yes	No	Yes	No	Yes

Notes: Outcome variable is the percentage change in annual income (%). All regressions include basic individual characteristics and use PS weighting. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. "Farming" refers to individuals who are engaged in agriculture work. "Not Disabled" refers to individuals whose physical ability are not severely limited due to diseases. Robust standard errors are clustered at village level. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table 10: Effect of Health on Labor Productivity and Time

	(1) Δ Overall	(2) Δ Productivity 1	(3) Δ Productivity 2	(4) Δ Labor Time
Sample: Farming				
Change in blood pressure	-0.0870***	-0.0378*	-0.0442**	-0.00182
	(0.0337)	(0.0204)	(0.0202)	(0.0202)
Observations	568	568	568	568
Sample: Not Disabled				
Change in blood pressure	-0.0828**	-0.0301*	-0.0281	-0.00408
	(0.0323)	(0.0178)	(0.0177)	(0.0177)
Observations	735	735	735	735
Sample: All				
Change in blood pressure	-0.0553*	-0.0299**	-0.0244*	-0.00454
	(0.0301)	(0.0144)	(0.0140)	(0.0142)
Observations	1,077	1,077	1,077	1,077

Notes: The outcome variable for column (1) is the changes in the overall index for the influence of disease on work. It takes the value between -4 and 4. The smaller the number, the worse the influence. The outcome variables for column (2)-(4) are the changes in the time index and productivity index 1 and 2, all of which take the value of -1, 0 and 1. A value of 1 indicates improved labor productivity or longer labor time compared to the previous year; -1 indicates reduced productivity or decreased time; 0 indicate no changes. Robust standard errors are reported in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Appendix

A Cluster v.s. Bootstrap

Table A.1: Robustness Checks for Standard Errors

	(1) Robust	(2) Cluster at Town	(3) Cluster at Village	(4) Bootstrap
Change in blood pressure	-5.209**	-5.209***	-5.209*	-5.209**
	(2.471)	(1.560)	(2.700)	(2.355)
Age	0.0292	0.0292	0.0292	0.0292
	(0.0428)	(0.0402)	(0.0498)	(0.0456)
Female ratio	0.00168	0.00168	0.00168	0.00168
	(0.00939)	(0.00872)	(0.00641)	(0.00923)
Log(income-12)	-0.801	-0.801	-0.801	-0.801
	(0.692)	(0.835)	(0.776)	(0.547)
Baseline Blood Pressure	-0.378**	-0.378***	-0.378**	-0.378**
	(0.160)	(0.134)	(0.181)	(0.153)
Observations	541	541	541	541

Notes: Outcome variable is the percentage change in annual income (%). All regressions include basic individual characteristics. The specification used is include health variables and exclude town variables. Standard errors are not clustered in column (1), clustered at town level in column (2), clustered at village level in column (3), and bootstrapped in column (4). Significance level: *** p<0.01, ** p<0.05, * p<0.1

B Using Two Instruments

This appendix section presents supplementary result using two instruments $IV1$ and $IV2$: $IV1 = 1$ if the individuals are treated by intervention 1, and $IV2 = 1$ if the individuals are treated by intervention 2. Specifically, we perform the following empirical analysis:

$$\Delta bp_i = \gamma_1 + \gamma_2 IV1_i + \gamma_3 IV2_i + \gamma_4 X_i + \epsilon_i \tag{4}$$

$$\Delta LogInc_i = \rho_1 + \rho_2 \Delta bp_i + \rho_3 X_i + \upsilon_i \tag{5}$$

where X is a vector of variables including Cov, $logInc12$, and $BP12$. Robust standard errors are clustered at village level.

Main results and placebo test results are reported in Table A.2 and Table A.3, which are almost identical as the results using only one instrument.

Table A.2: IV Regressions Using Two Instruments

	(2) IV	(3) IV	(4) IV	(5) IV
Sample: Not Disabled				
Change in blood pressure	-4.463***	-5.069***	-4.292***	-4.831***
	(1.717)	(1.962)	(1.616)	(1.817)
Age	-0.00127	-0.00477	0.0188	0.0169
	(0.0462)	(0.0473)	(0.0472)	(0.0482)
Female ratio	0.00121	0.000701	0.00139	0.000738
	(0.00611)	(0.00644)	(0.00623)	(0.00656)
Log(income-12)	-0.480	-0.384	-0.605	-0.526
	(0.693)	(0.662)	(0.745)	(0.721)
Baseline Blood Pressure	-0.343***	-0.380***	-0.331***	-0.363***
	(0.107)	(0.125)	(0.100)	(0.114)
Observations	735	735	708	708
Include Health Variables	No	No	Yes	Yes
Include Town Variables	No	Yes	No	Yes
Sample: Farming				
Change in blood pressure	-6.557**	-8.825**	-6.394**	-8.841**
	(3.030)	(4.116)	(2.884)	(3.786)
Age	0.0123	-0.0153	0.0110	-0.0164
	(0.0626)	(0.0707)	(0.0623)	(0.0753)
Female ratio	0.00437	0.00455	0.00212	0.00126
	(0.0118)	(0.0134)	(0.0120)	(0.0139)
Log(income-12)	-0.306	-0.0888	-0.530	-0.316
	(0.687)	(0.704)	(0.751)	(0.782)
Baseline Blood Pressure	-0.462**	-0.621**	-0.449**	-0.615**
	(0.217)	(0.285)	(0.217)	(0.267)
Observations	566	566	541	541
Include Health Variables	No	No	Yes	Yes
Include Town Variables	No	Yes	No	Yes

Notes: Outcome variable is the percentage change in annual income (%). All regressions include basic individual characteristics and use PS weighting. "Health variables" include salt control, fat control, anti-hypertension drug usage, and in-patient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. "Farming" refers to individuals who are engaged in agriculture work. "Not Disabled" refers to individuals whose physical ability are not severely limited due to diseases. Robust standard errors are clustered at village level. Significance level: *** p<0.01, ** p<0.05, * p<0.1

Table A.3: Placebo Tests Using Two Instruments

	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV
Sample: Disabled					
Change in blood pressure	-0.534	-2.521	-0.296	-2.575	-0.875
	(0.548)	(2.198)	(2.138)	(2.094)	(2.069)
Age	0.0778	0.0992**	0.0897*	0.0885*	0.0799*
	(0.0475)	(0.0489)	(0.0463)	(0.0465)	(0.0459)
Female ratio	0.0126	0.0148	0.0148	0.0117	0.0125
	(0.0115)	(0.0111)	(0.0111)	(0.0111)	(0.0112)
Log(income-12)	-0.424	0.0686	-0.438	0.0231	-0.422
	(0.731)	(0.782)	(0.709)	(0.737)	(0.697)
Baseline Blood Pressure	-0.157***	-0.283**	-0.140	-0.287**	-0.176
	(0.0417)	(0.129)	(0.130)	(0.124)	(0.126)
Observations	331	342	331	342	331
Include Health Variable	Yes	No	Yes	No	Yes
PS Weighting	No	No	No	Yes	Yes
Sample: Not Farming					
Change in blood pressure	-0.404	0.0970	1.199	0.0969	1.062
	(0.428)	(1.336)	(1.901)	(1.236)	(1.749)
Age	0.0552	0.0439	0.0527	0.0511	0.0547
	(0.0400)	(0.0471)	(0.0466)	(0.0380)	(0.0373)
Female ratio	0.0114	0.0104	0.0127	0.0101	0.0129
	(0.0107)	(0.00928)	(0.0108)	(0.00970)	(0.0113)
Log(income-12)	0.109	0.357	0.0767	0.346	0.106
	(0.502)	(0.579)	(0.460)	(0.603)	(0.487)
Baseline Blood Pressure	-0.117***	-0.107	-0.0308	-0.109	-0.0403
	(0.0404)	(0.0778)	(0.114)	(0.0698)	(0.102)
Observations	498	511	498	511	498
Include Health Variable	Yes	No	Yes	No	Yes
PS Weighting	No	No	No	Yes	Yes

Notes: Outcome variable is the percentage change in annual income (%). All regressions include basic individual characteristics and use PS weighting. "Health variables" include salt control, fat control, anti-hypertension drug usage, and inpatient records. "Town variables" include the number of residents in the town and the distance from the town to county seat. "Farming" refers to individuals who are engaged in agriculture work. "Not Disabled" refers to individuals whose physical ability are not severely limited due to diseases. Robust standard errors are clustered at village level. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$