Indoor air pollution and child health:
Evidence from stove and behavioral interventions in rural China

Fei Yu*
Colby College

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* Corresponding Author: Fei Yu, Assistant Professor of Economics, Colby College, 5230 Mayflower Hill, Waterville, ME 04901-8840 fax: 207-859-5229 tel: 207-859-5245 email: feiyu@colby.edu

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Abstract

For developing countries, indoor air pollution (IAP) is a serious health risk and is a major cause of acute respiratory infections (ARI). This paper analyzes the empirical evidence from a World Bank/Government of China project completed in 2006, where 5,500 rural households in four provinces in China were subject to different combinations of improved stove and behavioral interventions to reduce IAP exposure. This paper estimates the health effects of these interventions, providing the basis for a cost-benefit analysis. Difference-in-difference and matching estimates show the interventions led to significant reductions in ARI incidence among children five years of age and under. The cost-benefit analysis shows that both the combination of stove and behavioral interventions and behavioral interventions alone generate health benefits far exceeding the costs. Behavioral interventions alone, however, are found to be more cost effective.

1. Introduction

Indoor air pollution (IAP) is a leading health risk factor for rural households in developing countries (Ezzati, et al, 2002b). The combination of heavy reliance on solid fuel (biomass and coal) and low efficiency stoves, together with poor ventilation, results in dangerous levels of pollutants in the form of gases and suspended particulates (Smith, 1999). Although detailed epidemiological and toxicological research on the health effects of IAP is still at an early stage, there is increasing evidence that it is a causal agent of acute respiratory infections (ARI), chronic obstructive pulmonary disease, lung cancer, tuberculosis, nasopharyngeal and laryngeal cancers, and asthma. It may also cause low birth weight and prenatal mortality (Rehfuess and Rouse, 2005).

Of 20 leading health risk factors in very low and low income developing countries, IAP ranks, respectively, as the fourth and eighth most important mortality risk factor (WHO; 2002). It accounts for more than 500,000 deaths annually in China, and ranks as the fourth most important cause of loss of a healthy life (DALYs)[1] in developing countries (Ezzati and Baris ed. 2007). Women and children are particularly affected by IAP, as normally they are in the cooking area or home environment much longer than other family members.

During 2002-2006, the World Bank, in collaboration with the Government of China (Center for Disease Control), conducted an extensive IAP project in four provinces: Shaanxi, Guizhou, Gansu and Inner Mongolia. The project designed and distributed affordable improved stoves and conducted behavioral activities in selected

[1] Disability-adjusted life years (DALYs) lost to mortality is the total discounted value of years lost to premature death across all causes and age groups. DALYs lost to disability are based on the incidence and duration of various types of disability multiplied by a weight that accounts for the severity of the disability compared to loss of life. Total DALYs result from the sum of DALYs lost to mortality and disability, adjusted by a discount rate so that years of life lost at different ages are given different relative values (Nuria Homedes, 1995).

townships to reduce indoor air pollution, exposure to it and, thereby, to lower the associated health risks. Some 5,500 households were included in the project.

This paper estimates the reductions in ARI incidence attributable to these interventions, and the associated benefits and costs in monetary terms. Moreover, it examines the relative cost effectiveness of new stove technologies in combination with behavioral interventions, versus the latter alone. Based on this analysis, policy implications are addressed regarding indoor air pollution. The paper utilizes a household level data set compiled under the World Bank/Government of China project. This is one of the first attempts to quantify, at the household level, the net health benefits of alternative IAP interventions.

2. Background

2.1 Literature Review

There is a large literature concerning household energy use, but the early publications tended to report on improved stove projects in developing countries and their contribution to energy efficiency, with relatively little attention to the health benefits of reduced IAP. Projects in this category include the government sponsored National Improved Stove Program in China (Smith et al, 1993) and smaller projects in India, Mongolia, Nepal and Mexico. As pointed out by review studies, these projects sometimes had unintended negative effects for indoor air quality (Sinton et al, 2004). More recent projects have shifted the focus to improving indoor air quality. The World Bank/Government of China project examined in this paper is one of the largest with this objective.

Studies of the health implications of IAP exposure are concerned with causally linking IAP to certain diseases and quantifying – where possible – this relationship. One study reviewed more than 100 papers reporting health effects of household solid fuel combustion in China (Zhang and Smith, 2003). Another survey reviewed 13 recently published studies that quantify the relationship between exposure to IAP and ARI in young children (Smith et al, 2000). A recent study in this category is the randomized intervention trial being carried out in the Western Highlands of Guatemala (Smith et al, 2006).[2]

ARI includes a complex group of conditions of various aetiology and severity.[3] Non-serious Acute Upper Respiratory Infections (AURI) include the common cold, sinusitis, tonsillitis, otitis media and pharyingitis. Potentially life-threatening Acute Lower Respiratory Infections (ALRI) include pneumonia, bronchitis, bronchiolitis and laryngitis. From the public health perspective, ALRI is of greater concern as it results in most of the costs associated with ARI, including loss in DALY.

Some 20 studies have been cited as indicating strong evidence of IAP as a source of ALRI among children five and under in rural households in developing countries (Rehfuess and Rouse, 2005). In terms of relative risk, children five and under exposed to indoor smoke are indicated as more than twice as likely to suffer from pneumonia as children not exposed.[4] Children under one year of age are particularly susceptible to ALRI, due to their immature immune systems. In developing countries, they normally suffer at least one episode of ALRI every 2-3 years (Lanata 2004).

[2] Publications associated with this project are listed on the website: http://ehs.sph.berkeley.edu/guat/page.asp?id=07
[3] Aetiological agents may include diphtheria, influenza, pertussis and measles.
[4] It is also stated that women exposed to indoor smoke are more than three times as likely to suffer from chronic respiratory disease than women not exposed (Smith et al, 2004).

Children are quickly responsive to reductions in indoor air pollution, hence ARI evaluations can be undertaken fairly shortly (6 months) after IAP interventions. The best form of ARI evaluation is a physician-based assessment of pneumonia in children. A questionnaire-based assessment of respiratory disease is much less reliable, especially when conducted before and after the IAP interventions; the first survey alerts those interviewed to the nature of the problem, influencing responses during the second survey and thereby potentially adding to those citing ARI symptoms.

A critical review of the quantitative literature and data sources in nine countries found consistent evidence indicating a significant increase in the risk of ALRI for children exposed to IAP (Smith et al., 2000). Since ALRI is a chief cause of death of children in developing countries, the authors conclude that "there is an urgent need to conduct randomized trials to increase confidence in the cause-effect relationship (between IAP and ARI), to quantify the risk more precisely, to determine the degree of reduction in exposure required to significantly improve health, and to establish the effectiveness of interventions" (Smith et al 2000).

While there is a relatively large literature on the health effects of IAP, estimates of the health benefits from IAP interventions at the household level are few. Household level analysis is important because it provides the micro foundation for formulating public policy initiatives. The ARI implications for children five and under are an important component of this analysis.

2.2 The Project and Associated Data

2.2.1 The World Bank/Government of China IAP Project

During 2002-2006, the World Bank and Government of China tested affordable household energy technologies and behavioral interventions designed to substantially reduce IAP and exposure to it and, thereby, to lower the associated health risks (Ezzati and Baris ed, 2007). Eleven townships were selected to test the interventions, three in each of Shaanxi, Guizhou and Gansu provinces, and two in Inner Mongolia. Criteria for site selection included similar economic and housing conditions, a preponderance of rural households, geographical separation of the sites, low family incomes, women and children family members, and reliance on solid fuels (coal and biomass) for heating and cooking purposes.

One of three townships for each province (with the exception of Inner Mongolia involving only two townships) was subject to the full range of interventions, combining stove and ventilation improvement with health education. New improved stoves (with chimney) were provided at approximately one-third of the full cost[5]. The second township for each province was subject to only health education and other activities to induce behavioral changes, although improved stoves were available for purchase. The third township for each province served as a control group, where no interventions were undertaken. Within each township, seven to eight villages were selected randomly to participate in the project[6]. With few exceptions, all households in the selected villages agreed to participate. In this way, ex ante and ex post ARI incidence for each of the stove and behavioral intervention (S+B) and partial (B) intervention townships could be

[5] The households were mainly responsible for labor and some material cost for installing the stoves.
[6] Townships in China include large administrative areas, often containing dozens of villages.

compared with those for the control (C) townships, providing the basis for estimating the health effects of the interventions. Five hundred households from each township were selected for participation, for a total of 5,500. Assignment of treatment followed a cluster randomized design, reflecting the need to avoid cross contamination among households, and to facilitate the logistics of organizing intervention activities.

Almost 2,500 households in the study areas were assisted in acquiring new stoves and in improving the chimney/ventilation systems. Another 700 households undertook stove and/or chimney improvements at their own expense. The new stove technologies were designed and tested to meet local conditions and needs in each of the study provinces. Health education and behavioral activities were extensive, directly involving 3,500 study households and 5,000 students. The health education materials were prepared by local education and health experts, emphasizing the health risks of IAP exposure and the behavioral options for minimizing exposure[7]. They were presented in the local media and included in school and social mobilization activities, such as workshops, forums, field visits and demonstrations.

2.2.2 The Surveys, On-Site Measurement and Health Evaluations

The several phases of the IAP study generated extensive data sets. Household, health and other surveys, together with tests concerning energy use, on-site measurement of household IAP levels, and health evaluations, were conducted before and after the interventions.

The baseline household, health and other surveys were conducted in March and April, 2003 and the post-intervention surveys were conducted in April and May, 2005. .

[7] The World Bank project report (Ezzati and Baris eds, 2007) details the activities that took place and the content of the educational material. All original health education/behavioral material can be found on the CDC website: http://www.54rz.com/iap/eg/index.asp

The stove and ventilation interventions were undertaken during August to December 2004. The behavioral interventions were carried out over a six-month period in the second half of 2004. Baseline bi-weekly health evaluations were conducted from March to May 2003, and from March to June 2005 after the interventions. Figure 1 shows the timeframe of the relevant project activities.

Surveys were conducted for all households involved in the project, including questions about general household information and stove and energy use characteristics. Most respondents were female household members. Health questionnaires applied to all women and children in the project households, including information on general health conditions and IAP-related health symptoms. The surveys were conducted by the staff of provincial and county Health Bureaus and Centers for Disease Control and Prevention.

Field workers trained according to the WHO Integrated Management of Childhood Illness (IMCI) procedures conducted ARI evaluations for all children aged five and under in the project households. The field workers examined the children (some 300-500 in each province) bi-weekly for six times before the project interventions and eight times after.[8] The evaluations included questions posed to mothers about their children regarding ARI symptoms, such as cough, phlegm, difficult breathing, runny nose, sore throat, ear pain, etc. In addition, the children were examined for breathing frequency, chest in-drawing and other danger signs of ALRI.

2.2.3 Background Information about Project Localities and Populations

Compared to the national averages, the project areas have low income levels and high illiteracy rates (especially for females). Further, they have substantial ethnic minorities

[8] As noted earlier, children are quickly responsive to reductions in indoor air smoke, hence ARI evaluations can be undertaken fairly shortly (6 months) after IAP interventions.

(with different languages) and largely rural populations heavily reliant on farming for their livelihoods. Income levels, illiteracy rates and ethnicity have important implications for stove and fuel type, and stove-use practices (Ezzati and Baris ed, 2007).

Project households in Gansu and Inner Mongolia rely entirely on biomass fuels during the non-heating season, and use a combination of biomass and coal during the heating season. Guizhou relies more on biomass than coal during the non-heating season but reverses this pattern during the heating season. In a substantial number of cases, especially in Gansu, improved cooking stoves (from the earlier National Improved Stoves Program) were in use prior to the World Bank project interventions.

The baseline PM data collected by the project team indicated high levels of particulate matter (PM) in all provinces. The highest mean PM level recorded in Gansu province exceeded the US EPA health guideline (65 $\mu g/m^3$) by as much as 13 times. After the interventions, Gansu and Inner Mongolia experienced dramatic reductions in PM levels, while the evidence is not conclusive for Guizhou and Shaanxi (Ezzati and Barris, 2007).

The KAP (knowledge, attitude, practices) survey indicated that, in all provinces and for all socio-demographic groups, the majority of respondents were aware that smoke from cooking and heating stoves is a health hazard. Knowledge about effective means to reduce IAP exposure was limited except for simple measures such as opening the window for ventilation.

3. The Dataset

In accordance with the need to distinguish between the two types of ARI, respiratory data for children five and under were categorized as either AURI or ALRI, based on the Integrated Management of Childhood Illnesses (IMCI) procedure. AURI includes coughing, some discomfort in breathing, and some combination of a sore throat, ear discharge and runny nose. ALRI, which is also called clinical pneumonia, includes severe coughing with fast and difficult breathing and chest indrawing[9].

Upon closer examination of the data for the four provinces, it was found that children five years of age or younger in the project households of Shaanxi province were reported as having virtually no incidence of ALRI before or after the interventions.[10] Since ALRI is the main health indicator of interest, Shaanxi province was excluded from the analysis.

Table 1 summarizes the ARI evaluation and incidence data. The ARI incidence rate is calculated as the number of ARI cases identified by field workers divided by the total number of ARI evaluations of children in the sample. In the public health literature ALRI incidence is commonly reported as episodes per child/year. Episodes per child/year is not used in this analysis because there is no clear consensus on defining the start and end of a discrete ALRI episode, which influences estimates of ALRI duration and incidence (Lanata 2004)[11]. Due to the definition of an episode, the incidence rates reported as cases over evaluations are typically higher than episodes per child/year.

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[9] Non-serious Acute Upper Respiratory Infections (AURI) include the common cold, sinusitis, tonsillitis, otitis media and pharyingitis. Potentially life-threatening Acute Lower Respiratory Infections (ALRI) include pneumonia, bronchitis, bronchiolitis and laryngitis (Lanata et al, 2004).

[10] In total, 464 children five and under were each examined six times before the interventions in Shaanxi Province; only two children were determined to have had ALRI, translating into an incidence rate of 0.0004%. After the interventions, 290 children were examined eight times, and no cases of ALRI were found. This means virtually zero incidence of ALRI, while the average ALRI incidence for the other provinces is 1.8%. The very low incidence of ALRI in Shaanxi may have been due to quality issues of diagnosis, or simply random factors.

[11] Lanata (2004) recommends that “a minimum of 14 days free of these combined symptoms should be required between the end of one episode and the beginning of the next. If symptoms recur within a period of less than 14 days, these days of symptoms, as well as the intervening symptom-free days, should be considered part of the immediately preceding episode.”

For all children in the project sample, the overall incidence of ALRI is shown to be 1.8%. However, the incidence rates vary widely among the treatment and control groups. The large variation in estimates of ALRI (clinical pneumonia) is likely due to a wide array of risk factors underlying ALRI in developing countries. Rudan et al (2004) found that ALRI incidence demonstrate a large variance and bimodal distribution using 28 studies around the world. Nonetheless, the range of ALRI incidence rates for children in the sample is consistent with previous studies on China's rural and semi-rural population. For example, a study by Zhang (1986) in a semi-rural area near Beijing city reported ALRI incidence rates as high as 6 to 8% among children five and under. A recent study in Guatemala indicates an ALRI incidence rate (total cases identified by field workers over total home visits) of 2.3% (Bruce, et al 2007). Figures 2 and 3 show the ARI evaluation results by time of evaluation and group; they do not demonstrate any identifiable trend.

The ARI dataset was then merged with the household, children's and women's survey data. Table 2 shows summary statistics of household, women's and children's characteristics. Significant differences exist between the groups in regard to fuel use, exposure and mother's and children's health history.

4. Methodology

The ARI indicators are used as dependent variables, including both the one-time evaluation results for each individual, and the incidence rates for the same individual over time. The analysis is based on difference-in-difference (DID) and matching estimators. Four DID estimators (with robust standard errors) and one matching estimator were employed, using panel data and individual mean ARI incidence rates:

(1) The first is a simple OLS estimator without controlling for individual fixed effects or any covariates. Without fixed effects, the coefficient is mostly driven by variation across individuals at a moment in time.

$$Y_{it} = \beta_{.} + \beta_1 G_i + \beta_2 A_{it} + \beta_3 G_i A_{it} + u_{it}$$

Y_{it} is zero or one for each evaluation of the child,

i indicates the individual,

t indicates time of ARI evaluation,

G_i is a dummy variable for treatment status,

A_{it} is a dummy variable indicating before (=0) or after treatment (=1)

$G_i A_{it}$ is the interaction term, individuals under treatment after intervention (=1)

β_3 is the average treatment effect,

u_{it} idiosyncratic errors.

(2) The second is an OLS estimator as in (1), with additional control variables including household, women's and children's characteristics[12].

$$Y_{it} = \beta_{.} + \beta_1 G_i + \beta_2 A_{it} + \beta_3 G_i A_{it} + \beta_4 X_{it} + u_{it}$$

X_{it} is a set of covariates.

Other notations are as previously defined.

(3) The third is a standard fixed effects estimator.[13] In this case, the coefficient is mostly driven by the variation over time for each individual. A robust variance

[12] Dummy variables for time of evaluation are also included in an alternative model specification, but the time dummies are generally not significant and the coefficients for the explanatory variables are very similar to the model specification without time dummies.

[13] The Hausman test does not reject the random effect model. The fixed effects model and random effects model yield nearly identical results. Only results from the fixed effects model are reported.

matrix estimator was employed to adjust for possible heteroskedasticity or serial correlation[14].

$$Y_{it} = \beta_{.} + \beta_2 A_{it} + \beta_3 G_i A_{it} + \beta_4 X_{it} + C_i + u_{it}$$

Where

X_{it} is a set of time varying individual characteristics (in this analysis change in fuel consumption),

C_i is a set of time invariant individual characteristics,

u_i is the idiosyncratic error,

Other notations are as previously defined.

In the fixed effects analysis, only changes in fuel consumption were controlled for as covariates. Other household, mothers' and children's characteristics were assumed to remain unchanged.

For estimators (4) and (5) that follow, first differencing of mean ARI incidence were used as outcome variables, rather than evaluation results (which were recorded as simply zero or one). The mean ARI rates per child were calculated for before and after the interventions, and the difference between the two for each child was taken as the new outcome variable. In this manner, the model also eliminates the unobserved individual effect.

(4) The fourth is a first-difference estimator:

$$\Delta Y_{it} = \beta_{.} + \beta_1 \cdot G_i + \beta_2 \Delta X_{it} + \Delta u_{it}$$

[14] The robust variance matrix estimator is valid in the presence of any heteroskedasticity or serial correlation, provided that T is small relative to the number of individuals (Wooldridge, 2001).

Where ΔY_{it} is the change in ARI incidence rates for the same individual before and after the interventions.

ΔX_{it} is the change in time varying individual characteristics before and after the treatment.

Δu_{it} is the change in u_i.

β_1 is the average treatment effect.

Other notations are as previously defined.

The key assumption underlying DID is that the outcome variable for both the control and treatment group follow the same time trend. However, if the time trends of the outcome variable are different between the two groups, the average treatment effect will be biased. Figure 4 shows a graphical illustration of the DID method and possible bias caused by different time trends between the two groups. Unfortunately, the time span of the ARI observations in this sample was not sufficiently long to detect pre-existing trends.

(5) The fifth is a matching estimator, using the same outcome variable as (4). Given the significant differences in summary statistics of the ARI sample, it is important to rule out bias caused by individual heterogeneity that may be correlated with treatment status. A matching estimator provides a useful robustness check.

Matching is widely used in the program evaluation literature, so as to eliminate any relationship between assignment of treatment and individual effects through selecting, duplicating and dropping observations from the original dataset. While propensity score matching is widely used, Abadie and Imbens (2006b) prove that in general bootstrapping is invalid and provides the wrong variance estimate. A procedure developed by Abadie and Imbens (Abadie and Imbens, 2001) was employed[15], which implements nearest-neighbor matching on the Mahalanobis distance with bias adjustment. The Abadie and Imbens (AI) procedure has two advantages: first, it does nearest neighbor matching based directly on the matching covariates rather than indirectly on the covariates via the propensity score, hence it calculates the correct standard errors without having to adjust for the variance due to the estimation of the scores and the matching itself; and second, the procedure implements bias adjustment, which is particularly important for this study because the sample sizes are small and the analysis is unlikely to achieve exact matches on important attributes.

The following description of the Abadie/Imbens procedure follows Abadie and Imbens (2006a) closely, including their notations and terminologies. To estimate the average effect of treatment, i.e. reduction of ARI risk, the procedure imputed the unobserved outcomes (i.e., outcome if there were no treatment for the treatment group) and outcome if there were treatment for the control group. The basic idea behind matching estimators is to impute the missing outcome by finding other individuals in the data whose covariates are similar but who were exposed to the other treatment.

$$Y_i \equiv Y_i(W_i) = \begin{cases} Y_i(0) & \text{if } W_i = 0 \\ Yi(1) & \text{if } W_i = 1 \end{cases}$$

Where Yi(0) is the outcome obtained by individual i if under the control group, Yi(1) is the outcome obtained by individual i if under the treatment group.

The average treatment effect on the treated (ATT) can be expressed as:

[15] A recent paper by Barro, Machado and Galdeano (2008) uses the Abadie Imbens matching estimator in estimating the impact of extra health insurance coverage beyond a National Health System on the demand for several health services.

$$\tau^{p,t} = E[Y_i(1) \quad Y_i(0) | W_i = 1] \qquad and \qquad \tau^{p,t} = \frac{1}{N_1} \sum_{W_i = 1} (Y_i(1) \quad Y_i(0))$$

Where $N_1 = \sum_{i=1}^{N} W_i$ is the number of individuals in the treatment group.

The primary assumption that underlies matching is the conditional independence assumption (CIA), which posits that the treatment status is random conditional on some set of observed X variables or covariates.

Assumption: For all x in the support of X

(i) (unconfoundedness) W is independent of Y(0), Y(1) conditional on X=x

(ii) (overlap) c<Pr (W=1|X=x)<-c, for some c.

Unconfoundedness is not directly testable although there are indirect ways of testing, which typically rely on estimating a pseudo causal effect that is known to equal zero. A pseudo treatment test was conducted to determine the validity of the matching covariates used in the matching model. The overlap assumption requires that the propensity score is strictly between zero and one. In practice, a direct method of testing this assumption is to inspect the distribution of the propensity score in both treatment groups, which can reveal lack of overlap in the multivariate covariate distributions. Figure 5-9 show the estimated propensity scores for all treated and control units used in the matches. After trimming extreme values in some cases, all the bins are away from zero and one, which rejects lack of overlap.

Abadie and Imbens (2006a) show that the matching estimator of the treatment effect has a term corresponding to the difference in covariates between pairs of matched units. This term can be estimated based on two regression functions. Abadie and Imbens approximate these regression functions by linear functions and estimate them using least squares on the matched observations. Abadie and Imbens show that the adjustment term can be estimated as follows:

$$\hat{\mu}_{\omega}(x) = \hat{\beta}_{\omega 0} + \hat{\beta}_{\omega 1}\, x,$$

For $\omega = 0,1$ indicating the treatment received, where

$$(\hat{\beta}_{\omega 0}, \hat{\beta}_{\omega 1}) = \arg\min \sum_{i:W_i=\omega} K_M(i) \cdot (Y_i - \beta_{\omega 0} - \beta_{\omega 1}^{'} X_i)^2$$

Where Y_i is the observed outcome, X_i is a set of covariates, $K_M(i)$ is the number of times the unit is used as a match. Based on the estimated regression functions, the missing potential outcomes are predicted as:

$$\tilde{Y}_i(0) = \begin{cases} Y_i & if \quad W_i = 0 \\ \frac{1}{\# J_M(i)} \sum_{l \in J_M(i)} (Y_l + \hat{\hat{\mu}}_0(X_i) - \hat{\mu}(X_l)) & if \quad W_i = 1, \end{cases}$$

And

$$\tilde{Y}_i(1) = \begin{cases} \frac{1}{\# J_M(i)} \sum_{l \in J_M(i)} (Y_l + \hat{\mu}_0(X_i) - \hat{\mu}_0(X_l)) & if \quad W_i = 0, \\ Y_i & if \quad W_i = 1 \end{cases}$$

With corresponding estimator for the average treatment effect:

$$\hat{\tau}_M^{bcm} = \frac{1}{N} \sum_{i=1}^{N} (\tilde{Y}_i(1) - \tilde{Y}_i(0))$$

$J_M(i)$ is the set of indices for the matches for unit i that are at least as close as the Mth match. W_i is a dummy variable indicating treatment status, 0 for control and 1 for treatment. $Y_i(0)$ is the outcome without treatment; and $Y_i(1)$ is the outcome with treatment.

The selection of the matching covariates for this analysis was based on observed differences between the treatment and control groups, regression results on the effect of control variables on incidence of ARI, and on theory and earlier work in the field of IAP and respiratory infections. The validity of the matching covariates was examined through a pseudo treatment test using pre-treatment data. Based on the results of these tests, the observations were matched on a set of household, fuel and mothers' and children's characteristics. For AURI analysis, initial levels of AURI rates are used as a matching covariate. For ALRI analysis, this was not possible because the rare occurrence of ALRI causes difficulty in finding matches and lead to significant compromise of matching quality.

Specifically, children are matched on whether they are under one year of age at the time of the first evaluation; the literature indicates that children under one year of age have a significantly higher incidence of ALRI. For children 1-5 years old, age is not used as a matching covariate due to lack of evidence that it affects the incidence of ALRI in exploratory regression analysis of all the covariates, either in terms of linear effects or non-linear age group specific effects. The children were also matched according to per capita household consumption, storage of agricultural products, tobacco smoking in the household, fuel consumption, presence of a heating stove in the house, mother's cooking time, mother's history of respiratory infections, children's general health, and children's exposure time to smoke from cooking.

The matching covariates affect ARI incidence either through affecting indoor air quality or through exposure to it. It is obvious that household fuel and stove characteristics affect indoor air quality due to differences in emissions and fuel efficiency. Mothers' characteristics mainly affect stove use practice and exposure. Consumption and storage of agricultural products is a proxy for income and nutrition, which affects children's health endowment, as well as indoor air pollution, such as heating time, quality and quantity of fuel and stove, ventilation and housing structure. Children's health and exposure characteristics affect their vulnerability to infections.

In general, for large sample sizes, increasing the number of matches increases the statistical significance of the estimates, but at the expense of greater bias. However, in this analysis the sample sizes are relatively small and increasing the number of matches actually reduces the statistical significance of the estimates. This is probably due to the limited number of good quality matches when the sample size is small. Therefore, the analysis reports results under single nearest neighbor matching, with replacements. The analysis also corrects for heteroskedasticity in the treatment effect due to differences in covariates. This was achieved through matching similar individuals within the treatment groups and within the control groups. Finally, the analysis employed a bias-corrected matching estimator, based on the same set of covariates as used for matching.

5. Results

Table 4 presents the average treatment effects (ATE) for the interventions. The average treatment effect was estimated with ALRI and AURI indicators as outcome variables for two types of intervention groups compared with the control group, and for the marginal effect of adding a new stove to behavioral interventions (comparison of the stove plus behavioral intervention group and the behavioral intervention group). Seven estimators are reported: a simple DID estimator without controls, a DID estimator with controls (a broad set of household, mother's and children's characteristics as included in

Table 1: Summary Statistics), a DID estimator with individual fixed effects and controls for change in fuel consumption, a linear probability model using mean difference in ARI incidences before and after the interventions with controls, a propensity score matching estimator, an Abadie/Imbens matching estimator without bias adjustment, and with bias adjustment.

The estimates are generally consistent across models, with the Abadie/Imbens matching estimators yielding slightly larger and some times less significant estimates. In terms of ALRI, the estimated average treatment effect for the treated (ATT) ranges from a reduction of 4 to 6.5 percentage points (significant at 5% level) due to stove and behavioral interventions; the ATT for the behavioral intervention groups ranges from 2.8 to 3.6 percentage points. The ATT for AURI is somewhat larger for the behavioral intervention group (ranging from 19 to 20 percent) than for the stove plus behavioral intervention group (ranging from 12 to 19 percent).

There is no evidence of significant marginal benefit from adding stove interventions to behavioral interventions. The signs for the ALRI marginal effects are all negative, but not significant. The DID estimators indicate that the stove plus behavioral intervention group experienced less reduction in AURI incidence rates than the behavioral intervention group, which is implausible. This estimate becomes insignificant when the matching estimator is employed.

Table 5-7 shows a robustness check through examining matching quality. The difference in average covariate values by treatment status is normalized by the standard deviation of these covariates. If the matching were perfect, the normalized difference should be zero. In general, normalized differences are reduced significantly after matching. The matched samples presented in Tables 5-7 all have normalized differences less than 0.3[16], indicating that the matched data sets are well balanced.

The DID estimating procedure with controls provides insight about the factors that affect ALRI risk among children five and under. Fuel consumption (both biomass and coal) in the non-heating season is positively correlated with ALRI, due to the increase of IAP. However, biomass consumption in the heating season is negatively correlated with ALRI, despite the increase in IAP. This may show that indoor heating to maintain body warmth during the winter is important in helping to prevent ALRI, offsetting to some extent the ill effects of IAP. This point is corroborated by the finding that the presence of a heating stove reduces ALRI risk. Of course, both fuel consumption and heating can be correlated with income. Children's exposure time to ALRI is positively correlated with ALRI, which is expected. Mother's previous history of respiratory disease increases children's risk of ALRI.

[16] As a rule of thumb, normalized differences close to or greater than 0.4 indicate problem with matching quality.

6. Benefit/Cost Analysis

The economic value of reducing risk of ALRI and AURI can be calculated through applying willingness to pay (WTP) and value of statistical life (VSL) estimates for China. There is an extensive literature on the value of reducing risks of mortality and morbidity in the US and other industrial countries, but there have been few estimates using survey data from developing countries. Most benefit valuation studies for developing countries use a cost-of-illness approach, or have adapted VSL estimates from developed countries adjusting for differences in income. The cost-of-illness approach is a valuable alternative measure when there is little information on VSL. However, the approach has little basis in economic theory, as it takes the view that people are producers and assumes that improvements in health equate to the sum of reductions in labor market earnings and savings in health care expenditures (Berger, et al, 1994).

In this paper, benefit valuation is based on a study in China by Hammitt and Zhou (2006), as it seems to provide the most recent WTP and VSL estimates for the populations concerned. The Hammitt and Zhou (2006) study is one of the first that directly estimates the economic value of reducing health risk in developing countries. Hammitt and Zhou estimated the economic values for preventing colds, chronic bronchitis and fatality through a contingent valuation (CV) study. The CV surveys were conducted in Beijing, Anqing and rural areas near Anqing, to represent populations of a large city, a small city and a rural area of China. For rural areas in China, the mean VSL is estimated to be about $100,000 to $180,000, although estimates of the VSL are sensitive to modeling choices. This is much smaller than for the US and other industrialized countries.[17] The estimated median WTP to prevent a cold ranges from $3 to $5, and the mean WTP ranges from $4 to $10[18]. Again, these estimates are much smaller than estimates for the US and other developed countries[19].

The benefits from the project interventions are calculated in two parts: (1) the reduction in mortality due to ALRI; and (2) the benefit from avoiding AURI. The reduction in ALRI risk is converted to the number of saved lives. According to statistics for China, the five and under mortality rate due to ALRI is 4.15 per 1000.[20] Based on this, mortality due to ALRI for the treatment groups was calculated adjusting for the number of children in each group. The percentage reduction of ALRI risk was then applied to obtain the number of saved lives due to the interventions. The number of saved lives was then valued according to the VSL estimates in the Hammitt and Zhou (2006) study, to give the economic value of ALRI risk reduction.

As noted earlier, the ALRI reduction rates differ as between the stove plus behavioral intervention group and the behavioral intervention group. When compared to the control group, the stove plus behavioral group experienced a 4-6.5 percentage point reduction in ALRI incidence; for the behavioral intervention group, the reduction ranged from 2.5 to 3.6 percentage points. After taking into account baseline incidence rates and trends indicated by the control group, these percentage point reductions convert to reductions ranging from 40 to 80%. Since the earlier analysis showed that the differences in reduction rates between the two treatment groups were not statistically significant,

[17] Viscusi and Aldy conclude that the most reasonable values are $4 million to $9 million for the US.
[18] The average out-of-pocket expenses to treat the respondent's last cold are $2.
[19] Other studies have valued one-day avoidance of cold as between $10 and $150 for the US, $4 and $24 for Bangkok of Thailand, and $40 to prevent a cold in Taiwan (see Hammitt and Zhou 2006).
[20] The five and under mortality rate is 31 per 1,000 live births and the percentage of mortality due to ALRI for this age group is 13.4% (WHO 2006).

sensitivity analysis was used to show the possible range of benefits for both groups, rather than assigning different benefit values to these two groups. Sensitivity analysis was based on 40%, 60% and 80% reduction in ALRI rates.

This benefit evaluation procedure is subject to the implicit assumption that the estimate of ALRI reduction due to intervention is representative throughout the year. Previous studies have shown seasonal variations in ALRI. For example, ARI incidence peaks in December and January in Northern China (Zhang et al, 1986). Whether the risk reduction rate is also subject to seasonal variations is unknown. Another limitation is that mortality rates due to ALRI for China include both urban and rural areas. Given the fact that the intervention groups were at low income levels in rural or semi-rural setting, the mortality rate and the contribution of ALRI could be higher than assumed in the analysis, with the result that the benefits were underestimated.

In terms of AURI, each case is assumed to be one episode of common cold. Baseline data was used to calculate the annual number of cold episodes among children in the treatment groups. As mentioned earlier, cold incidence peaks in December and January. While the evaluations were undertaken in April, May and June, it is unknown whether the evaluation results were representative of the annual average. The effect of AURI reduction for children in the treatment group was calculated as episodes of cold avoided per year. An episode of cold was then valued according to the Hammitt and Zhou (2006) study. The differences in AURI reduction were not as big across groups and models as the case for ALRI. Similarly as in ALRI benefit valuation, sensitivity analysis was conducted for 40% and 55% reduction of ALRI incidence.

Table 8 presents benefit valuations based on alternative assumptions about willingness to pay measures and ARI risk reductions due to the interventions. The annual benefit estimates range from US $201 to US$736 per household. This range is much greater than the cost of interventions per household. Table 9 presents cost data from the IAP project. Assuming that the benefits of the project interventions continue for 10 years, the total costs for each component are amortized over this period at 5 and 10 % interest rates to reflect alternative opportunity costs of capital. Costs were calculated on a per household basis, to make it comparable with the benefit analysis. There were 500 households in each treatment/control group[21].

These costs are an approximate measure of the real cost of the intervention programs. For the stove intervention component, the costs include the costs for designing, purchasing and distributing the improved stoves. The development of stoves and marketing mechanisms would have spillover effects for populations other than the treatment groups. One can assume that if more households were involved in the project, the average cost per household would have been lower. The cost measure for this component may overestimate the real cost. In terms of the behavioral intervention component, the costs include development of training and publicity material, school curriculum on IAP education, expenses for conducting training workshops and awareness raising activities. However, this measure of cost does not include the opportunity cost of the time spent on IAP awareness education. This consideration is particularly relevant for students and teachers who were involved in the IAP educational programs, and health workers who conducted activities in villages to raise IAP awareness.

[21]Only around 100 households had children five or under.

The total cost for the stove plus behavioral intervention group includes the costs of both the stove and the behavioral intervention components. The total cost for the behavioral intervention group include only the cost of the behavioral component. These cost estimates do not include private costs incurred to improve stove and ventilation because unfortunately there is no information on private spending[22]. For both intervention groups, the costs per household were much smaller than the lower bound of the benefit estimates. While there was net benefit from both forms of interventions, behavioral interventions on their own appear to be more cost-effective than when combined with stove interventions.

7. Conclusions and Policy Implications

This paper analyzes the data generated from a World Bank IAP project in China, providing estimates of the reduction in ARI incidence from stove and behavioral interventions, and a cost benefit analysis of the interventions., The interventions resulted in measurable reductions of risk in ALRI and AURI among children five years of age and younger. These conclusions are robust to model specifications.

The analysis indicates that both stove and behavioral interventions were effective in reducing ALRI and AURL risk from IAP exposure, although adding the stove interventions do not result in statistically significant marginal benefit. In light of this finding, government interventions designed to help reduce health risks from IAP exposure should focus on modifying household behavior. However, the economics of household energy use, particularly market failure in developing clean fuel alternatives

[22] For households in the stove plus behavioral intervention group, new improved stoves were distributed largely free of charge, although the household members contributed labor to help install the stoves. For the behavioral intervention group, households had the option to buy new stoves and install them at their own expense.

and new stove technologies in low income countries, indicate room for government intervention in this regard as well.

The lack of significant marginal health benefit from the stove intervention also suggests the need for research on threshold effects and improvement of the stove intervention programs. The stove plus behavioral intervention group had higher baseline indoor pollution concentrations than other groups. The lack of marginal benefit from adding the stove to the intervention could possibly be due to a threshold effect, i.e. health damage caused by high pollution levels may not be as easily reversed as that caused by low pollution levels. Research is required concerning the concept of IAP/ARI thresholds, and the relative benefits of alternative policy interventions under differing baseline circumstances. Further, the issue of “moral hazard” of stove users needs to be examined, i.e. installation of improved stoves may cause household members to take less precautions to reduce their exposure to IAP.

There are several caveats to bear in mind when applying the conclusions in this study to other locations and communities. The sample size limits the statistical power to detect small changes. For example, the lack of marginal benefit from combining stove interventions with behavioral interventions could be too small to be detected with the available sample. The sample households were characterized by extreme poverty and low education levels, compared to the provincial averages. Conclusions based on these sample households may not apply to other populations, or need to be adjusted in other applications. Knowing that the IAP interventions in this study generated measurable health benefits is only a step in determining whether they are appropriate in addressing the IAP problem more generally.

Appendix

Figure 1 World Bank/China project activity timeline

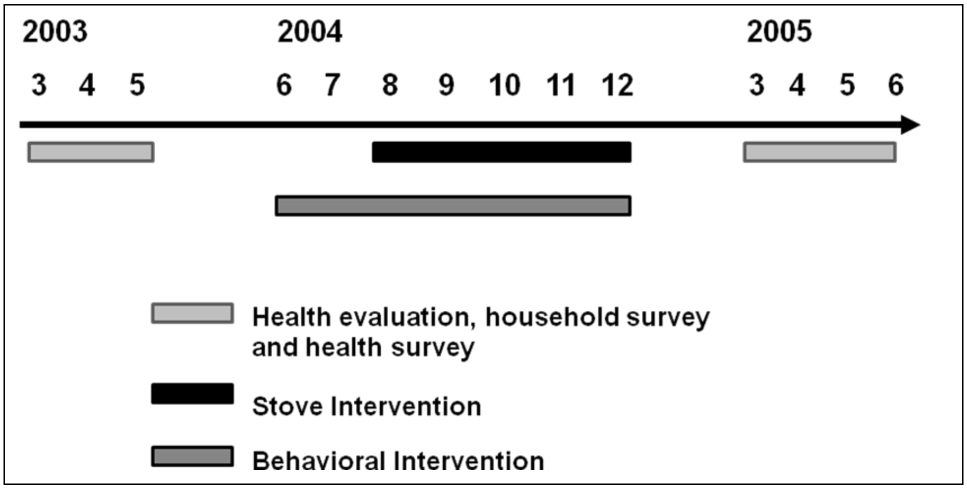
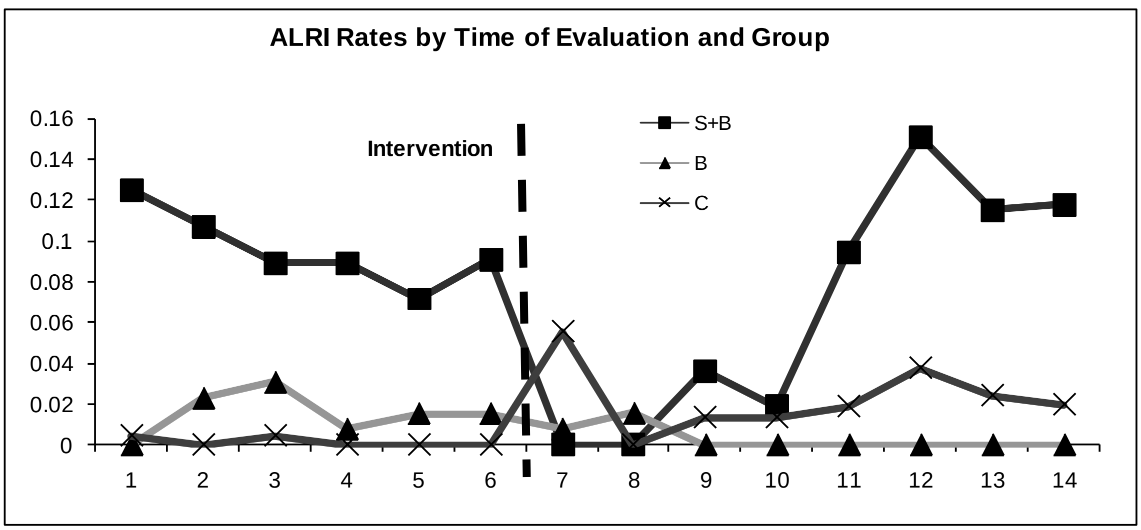
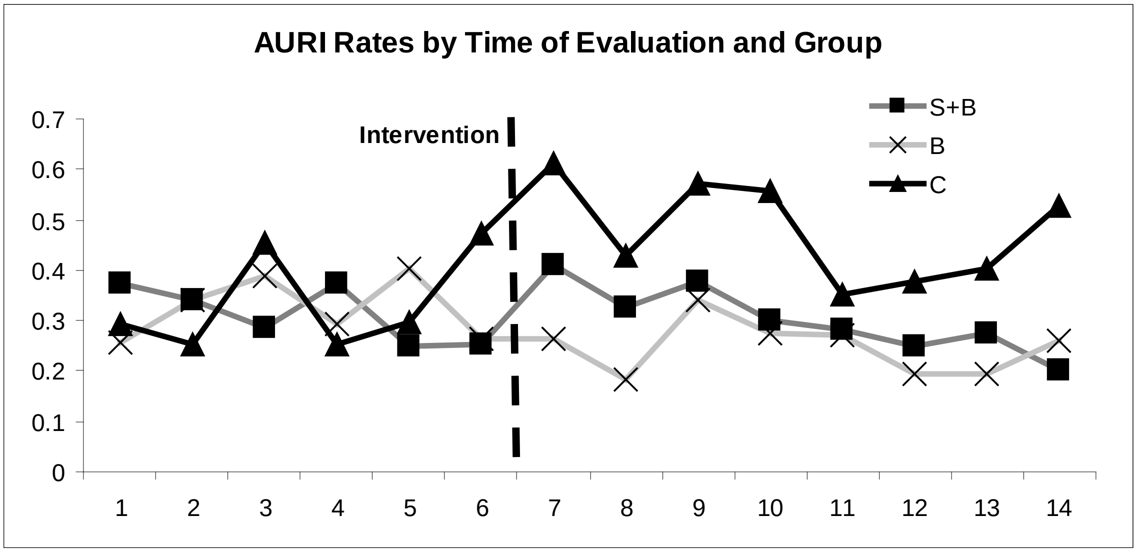


Figure 2. ALRI Rates by Time of Evaluation and Group



Mean ALRI rates are calculated for each group at each time of evaluation. Children were evaluated 6 times before and 8 times after.

Figure 3. AURI Rates by Time of Evaluation and Group



Mean AURI rates are calculated for each group at each time of evaluation. Children were evaluated 6 times before and 8 times after.

Figure 4a. Graphical Illustration of DID Method

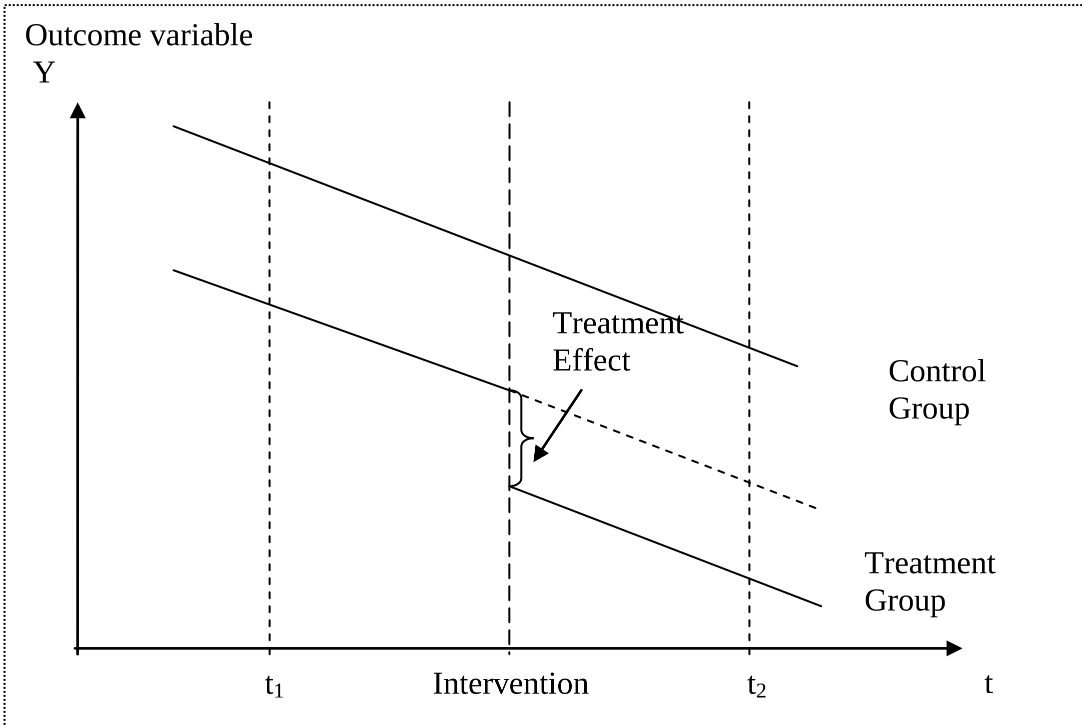


Figure 4b. Graphical Illustration of DID Estimate Bias Due to Different Time Trends

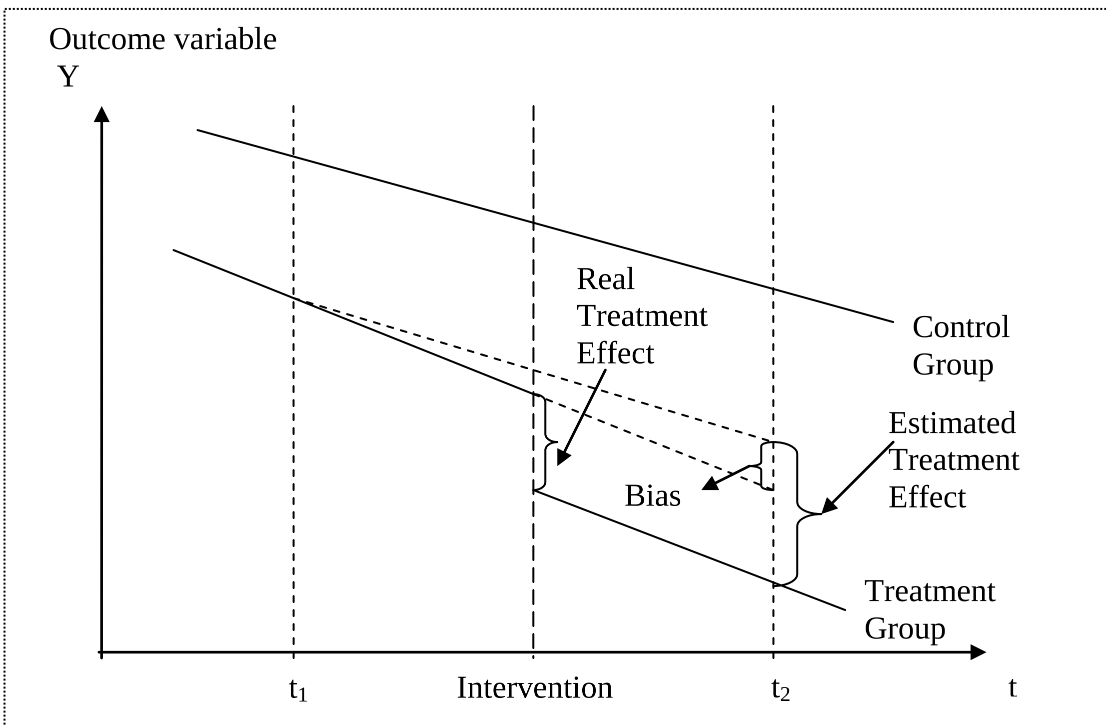


Figure 5. Estimated Propensity Score before Trimming (S+B and Control)

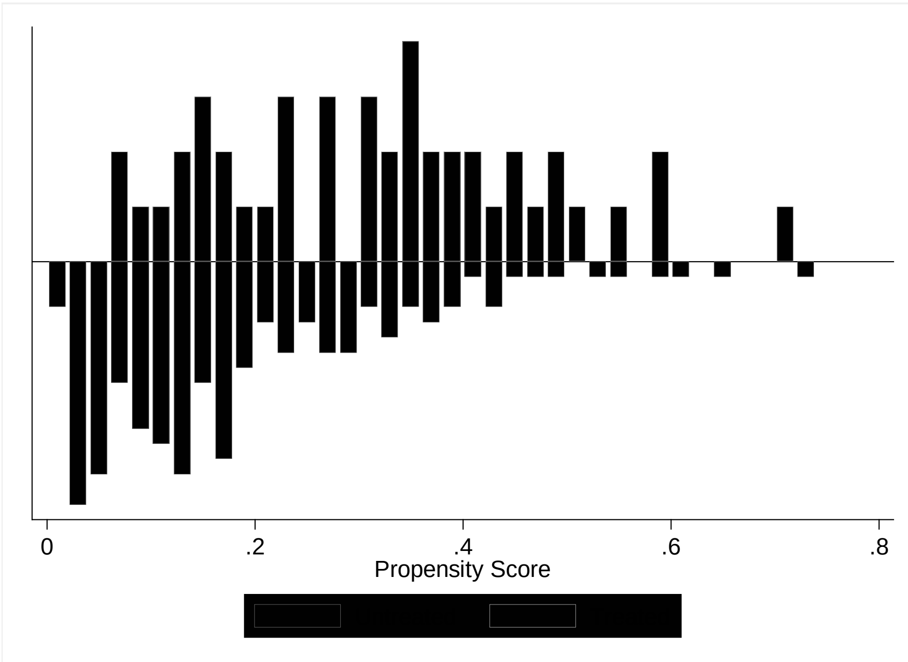
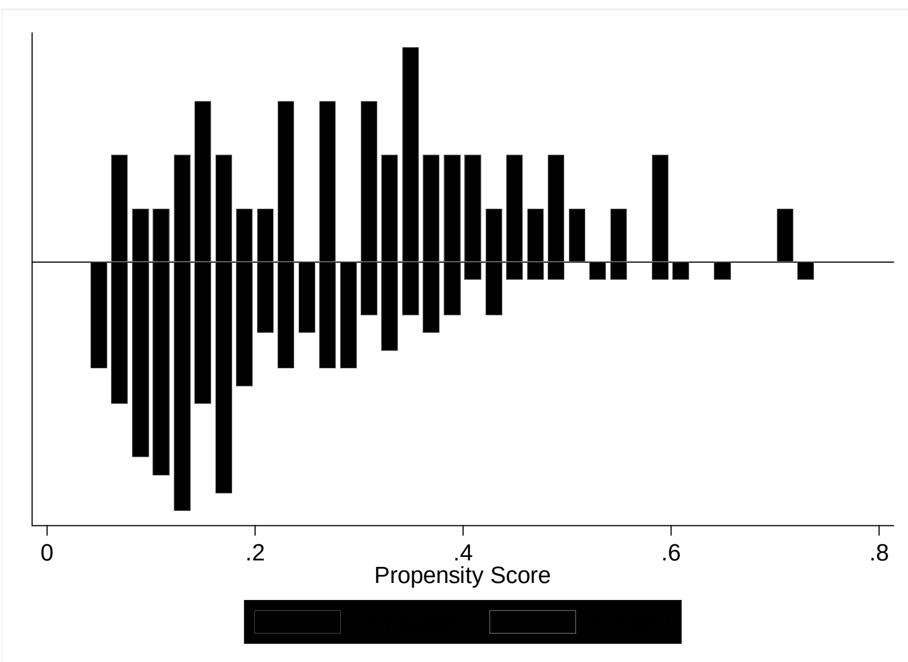


Figure 6. Estimated Propensity Score after Trimming (S+B and Control)



21 observations with propensity score less than .05 and greater than .95 were dropped from a sample of 208.

Figure 7. Estimated Propensity Score before Trimming (B and Control)

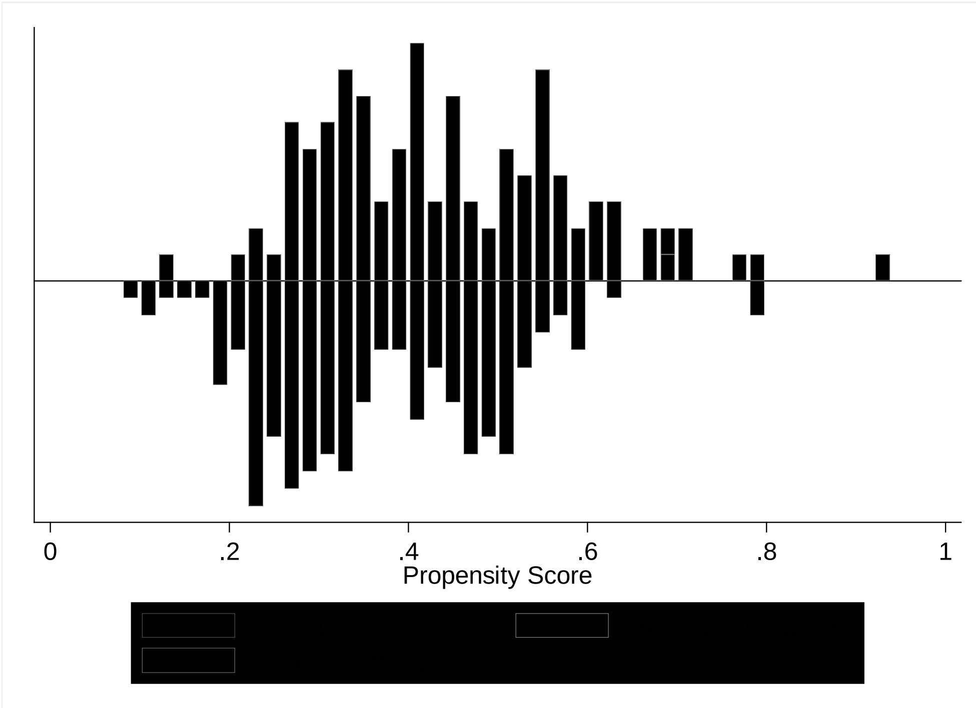


Figure 8. Estimated Propensity Score before Trimming (S+B and B)

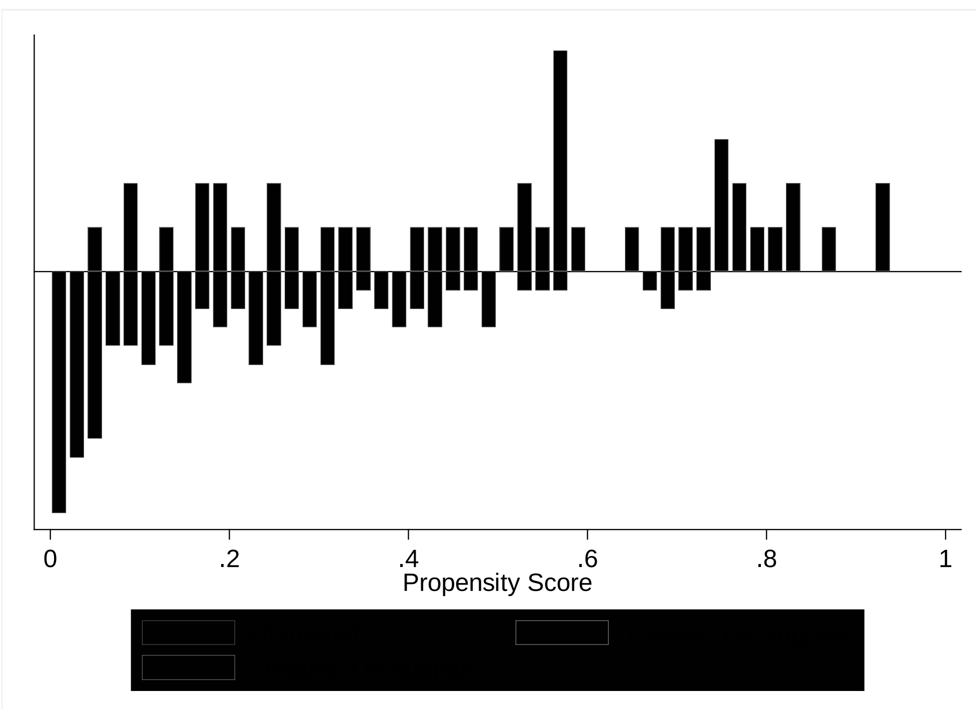
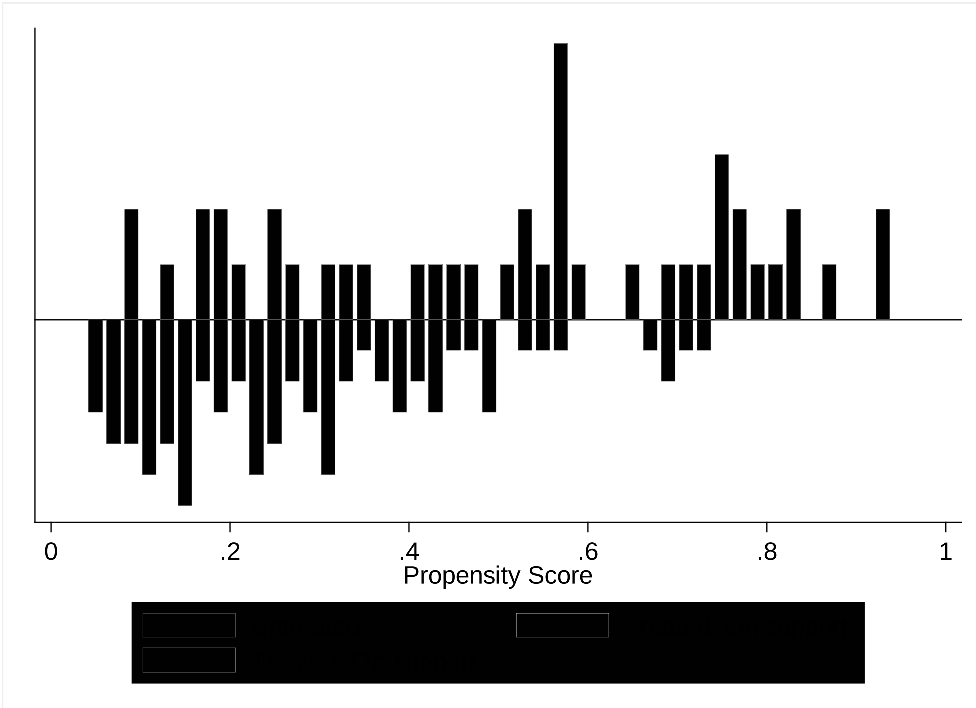


Figure 9 Estimated Propensity Score after Trimming (S+B and B)



30 observations with propensity score less than .05 and greater than .95 were dropped from a sample of 152.

Table 1 Summary Statistics of Household, Children's and Mother's Characteristics

Group	S+B			B			Control		Total	
	mean	sd	t-stat	mean	sd	t-stat	mean	sd	mean	sd
Household (n)	54			64			106		226	
Family Size	5.06	1.52	[3.24]	4.67	1.32	[1.39]	4.50	1.24	4.64	1.33
PC annual cash income (yuan)	319.51	285.63	[-0.96]	504.98	421.79	[1.88]	424.14	447.03	399.00	415.93
PC annual cash value of agr. Products for consumption of storage (yuan)	292.91	295.23	[-0.64]	370.51	222.87	[1.26]	338.57	261.24	327.60	269.91
Heating in the winter	0.56	0.50	[-1.40]	0.78	0.42	[1.67]	0.71	0.46	0.67	0.47
Baseline Fuel Use										
Total annual biomass use (jin)	2841.29	3167.76	[-2.23]	4287.54	8656.65	[0.20]	4173.65	6000.87	3853.47	5479.98
Total annual coal use (jin)	5618.26	4738.41	[2.90]	2822.84	3866.05	[-1.20]	3315.22	4241.80	3868.67	4466.93
Monthly biomass use for non-heating season	171.45	246.06	[-2.46]	299.71	722.29	[0.32]	284.82	485.91	257.58	442.58
Monthly biomass use for heating season	367.42	398.90	[-1.60]	472.46	732.82	[-0.02]	473.77	562.23	448.21	528.85
Monthly coal use for non-heating season	451.74	422.03	[2.49]	200.23	267.07	[-1.84]	262.90	353.69	308.28	379.12
Monthly coal use for heating season	501.08	456.80	[2.94]	305.25	449.94	[0.05]	303.01	434.38	350.61	447.08
Change in Fuel Use Before and After the Interventions										
Change in avg. monthly biomass use	41.94	175.04	[-0.53]	83.75	224.41	[1.01]	55.58	162.60	59.83	183.85
Change in avg. monthly coal use	53.15	123.89	[-2.11]	212.23	420.26	[1.91]	121.86	241.62	129.52	286.83
Mother (n)	54			64			106		226	
Elementary school plus	1.69	0.47	[-0.62]	1.84	0.37	[1.68]	1.77	0.42	1.75	0.43
Smoking	0.87	0.59	[-1.56]	1.06	0.48	[0.78]	1.02	0.50	0.98	0.52
Average Daily Cooking Time (min)	140.41	82.68	[0.26]	119.80	61.45	[-2.28]	135.02	69.91	136.31	73.04
History of Resporatary Desease	0.89	0.70	[-1.92]	0.61	0.52	[-5.23]	0.92	0.65	0.91	0.66
Children (n)	62			69			127		258	
Age	2.35	1.36	[0.025]	2.52	1.30	[1.09]	2.38	1.37	2.37	1.36
sex	0.47	0.50	[-1.18]	0.71	0.86	[1.54]	0.61	0.65	0.58	0.62
Daily exposure to cooking smoke	1.40	0.80	[-3.40]	1.79	1.19	[-1.45]	1.99	1.29	1.83	1.21
General health status	3.00	0.99	[-1.31]	2.93	0.86	[-1.92]	3.11	0.97	3.08	0.98

Table 2. ARI Evaluation Results and Incidence Rates by Group

Group	S+B	B	C	All
# Children evaluated	62	133	187	382
AURI cases	235	601	1297	2133
ex ante	106	303	450	859
ex post	129	298	847	1274
ALRI cases	61	16	32	109
ex ante	32	14	3	49
ex post	29	2	29	60
Child-times evaluation	767	2054	3322	6143
ex ante	336	843	1422	2601
ex post	431	1211	1900	3542
Times/child	12	15	18	16
ex ante	5	6	6	6
ex post	7	9	10	9
Crude AURI rate	30.6%	29.3%	39.0%	34.7%
ex ante	31.5%	35.9%	31.6%	33.0%
ex post	29.9%	24.6%	44.6%	36.0%
Crude ALRI rate	7.95%	0.78%	0.96%	1.77%
ex ante	9.52%	1.66%	0.21%	1.88%
ex post	6.73%	0.17%	1.53%	1.69%

Crude AURI/ALRI rates are calculated as AURI/ALRI cases divided by total evaluation times for all children.

Table 3. Individual ARI Incidence Rates Before and After the Interventions

Individual ALRI Rates

Before Interventions				After Interventions			
mean	sd	min	max	mean	sd	min	max
S+B							
9.9%	0.246	0	100%	7.5%	0.153	0	50.0%
B							
1.6%	0.095	0	100%	0.3%	0.016	0	12.5%
C							
0.3%	0.022	0	16.7%	1.8%	0.048	0	25.0%

Individual AURI Rates

mean	sd	min	max	mean	sd	min	max
S+B							
32.9%	0.304	0	100%	31.4%	0.322	0	100%
B							
36.2%	0.231	0	100%	23.4%	0.182	0	100%
C							
34.2%	0.256	0	100%	46.4%	0.277	0	100%

ARI incidence rates are calculated for each individual before and after the interventions.

Table 4 Estimates of Average Treatment Effect Due to Interventions

	ALRI			AURI		
Estimator	ATT	(s.e.)	t-stat	ATT	(s.e.)	t-stat
			S+B vs. C			
Simple DID	-0.041	*0.02*	*-2.03*	-0.146	*0.038*	*-3.87*
DID with Controls	-0.05	*0.024*	*-2.11*	-0.124	*0.043*	*-2.91*
DID FE with controls	-0.059	*0.018*	*-3.24*	-0.155	*0.035*	*-4.46*
Mean Dif with controls	-0.046	*0.027*	*-1.69*	-0.083	*0.057*	*-1.47*
PS matching	-0.057	*0.048*	*-1.19*	-0.236	*0.07*	*-3.37*
AI matching simple	-0.077	*0.051*	*-1.53*	-0.11	*0.06*	*-1.82*
AI matching Bias-adjusted	-0.065	*0.038*	*-1.68*	-0.193	*0.06*	*-3.19*
			B vs. C			
Simple DID	-0.028	*0.005*	*-5.12*	-0.243	*0.027*	*-9.11*
DID with Controls	-0.031	*0.006*	*-5.03*	-0.198	*0.028*	*-7*
DID FE with controls	-0.03	*0.005*	*-5.81*	-0.252	*0.026*	*-9.66*
Mean Dif with Controls	-0.025	*0.009*	*-2.47*	-0.202	*0.038*	*-5.27*
PS matching	-0.028	*0.012*	*-2.39*	-0.117	*0.044*	*-2.68*
AI matching simple	-0.036	*0.014*	*-2.48*	-0.209	*0.035*	*-5.96*
AI matching Bias-adjusted	-0.028	*0.014*	*-1.94*	-0.182	*0.035*	*-5.19*
			S+B vs. B			
Simple DID	-0.013	*0.021*	*-0.63*	0.097	*0.039*	*2.46*
DID with Controls	-0.011	*0.023*	*-0.48*	0.118	*0.045*	*2.62*
DID FE with controls	-0.02	*0.018*	*-1.11*	0.1	*0.37*	*2.07*
Mean Dif with Controls	-0.013	*0.041*	*-0.32*	0.194	*0.64*	*3.01*
PS matching	-0.031	*0.47*	*-0.67*	0.2	*0.072*	*2.78*
AI matching simple	-0.031	*0.037*	*0.395*	0.042	*0.062*	*0.68*
AI matching Bias-adjusted	-0.02	*0.037*	*-0.55*	-0.017	*0.062*	*-0.28*

Panel data analysis:

Simple DID is a OLS estimator of pooled regression model without controls.

DID with controls is an OLS estimator of pooled regression model with controls including mothers', children's and household characteristics.

DID FE with controls is a fixed effect estimator with change in fuel consumption as controls.

Mean difference as outcome variable (using change in ARI rates for each individual as the outcome variable):

Mean Dif with controls is an OLS estimator with fuel consumption change as controls.

PS matching estimator employs propensity score matching with kernel option.

AI matching simple is an estimator that follows Abadie Imbens nearest neighbor matching with replacement procedure, but without bias-adjustment.

AI matching bias-adjusted is an estimator that follows Abadie Imbens nearest neighbor matching with replacement and with bias-adjustment using all the matching covariates.

Table 5-7 Matching Quality: Normalized Difference of Covariates for Matched and Unmatched Samples

These tables show the difference in average covariate values by treatment status, normalized by the standard deviation of these covariates.

Table 5 Normalized Difference of Covariates (S+B and C)

	AURI		ALRI	
Variables	Unmatched	Matched	Unmatched	Matched
PC agr. consumption and storage	-0.127	-0.025	-0.127	-0.121
Monthly biomass use non-heating season	-0.187	0.023	-0.187	0.049
Monthly coal use heating season	0.232	0.126	0.232	0.195
Heating stove in the house	-0.091	-0.057	-0.091	0.028
Mother's daily cooking time	0.020	0.028	0.020	0.021
Under oneyear old at first survey	-0.109	0.046	-0.109	0.035
Smoking in the house	-0.203	0.068	-0.203	0.061
Mother's history of resporatory desease	-0.082	-0.006	-0.082	-0.038
Child health status	0.036	0.015	0.036	0.014
Child daily exposure time to cooking smoke	-0.378	0.051	-0.378	0.124
Baseline AURI rate	-0.313	-0.156		

Table 6 Normalized Difference of Covariates (B and C)

	AURI		ALRI	
	Unmatched	Matched	Unmatched	Matched
PC agr. consumption and storage	0.062	0.044	0.070	0.016
Monthly biomass use non-heating season	-0.239	-0.061	-0.230	-0.106
Monthly coal use heating season	0.273	0.155	0.266	0.061
Heating stove in the house	0.118	0.017	0.122	0.080
Mother's daily cooking time	0.017	-0.068	0.016	-0.019
Under oneyear old at first survey	0.061	0.056	0.058	-0.042
Smoking in the house	-0.088	0.039	-0.071	0.018
Mother's history of resporatory desease	-0.228	-0.067	-0.223	-0.145
Child health status	-0.068	-0.063	-0.067	-0.006
Child daily exposure time to cooking smoke	-0.034	0.001	-0.023	0.009

Table 7 Normalized Difference of Covariates (S+B and B)

	AURI		ALRI	
Variables	Unmatched	Matched	Unmatched	Matched
PC agr. consumption and storage	-0.074	-0.001	-0.161	-0.003
Monthly biomass use non-heating season	-0.013	0.010	0.136	0.114
Monthly coal use heating season	0.005	0.009	-0.123	0.019
Heating stove in the house	-0.069	-0.042	-0.091	-0.018
Mother's daily cooking time	0.091	0.020	0.174	-0.056
Under oneyear old at first survey	-0.046	-0.009	-0.143	-0.019
Smoking in the house	-0.073	-0.001	-0.080	-0.006
Mother's history of resporatory desease	0.195	0.014	0.407	0.151
Child health status	0.142	0.127	0.238	0.127
Child daily exposure time to cooking smoke	-0.155	-0.004	-0.137	0.013
Baseline AURI rate	-0.096	0.081		

Table 8 Benefit Analysis for the Interventions

Benefit Analysis for ALRI			
Percentage Reduction from Baseline Rate	**40%**	**60%**	**80%**
Total # children	195	195	195
Under Five Mortality Attributable to ALRI (per 1,000 births)1	4.15	4.15	4.15
Mortality Reduction for Treatment Group	0.3237	0.48555	0.6474
Valuation of benefit using VSL			
USD100000 (low)	32,370	48,555	64,740
USD180000 (high)	58,266	87,399	116,532
Benefit Analysis for AURI			
Percentage reduction from baseline rate	**40%**	**55%**	
Baseline Incidence rate of AURI	35%	35%	
Baseline Annual AURI cases2	1843	1843	
Annual AURI cases reduction	737	1014	
Valuation of benefit using WTP			
USD3 (low)	2211	3041	
USD10 (high)	7371	10135	
Total Benefit (USD)			
Low	34581	51596	66951
High	65637	97534	126667
Total # households with children over five	172	172	172
Total Benefit per Household (USD)			
Low	201	300	389
High	382	567	736

Notes:
1. Source: The World Health Statistics 2006, WHO
2. I assume that the AURI incidence obtained from the baseline evaluation (April, May and June) period is representative of the AURI incidence over a year.

Table 9 Summary of Project Costs for Each Province

Stove plus behavioral interventions	Cost (USD)
Total Project Cost	215,833
Annual cost over 10 years (5%)[1]	27,468
Cost per household[1]	55
Annual cost over 10 years (10%) [2]	34,224
Cost per household[2]	68
Behavioral interventions	
Total Cost	37,500
Annual cost over 10 years (5%)[1]	4,764
Cost per household[1]	10
Annual cost over 10 years (10%)[2]	5,952
Cost per household[2]	12
Marginal cost of stove intervention	
Total Cost	178,333
Annual marginal cost over 10 years (5%) [1]	22,704
Cost per household[1]	45
Annual marginal cost over 10 years (10%) [2]	28,284
Cost per household[2]	57

1. Assumes opportunity cost of capital of 5%.
2. Assumes opportunity cost of capital of 10%.

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