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Keep the Chimneys Working: Improved Cooking Stoves and Housewives' Health in the Peruvian Andes

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Abstract

This paper examines the effects of long term improved cooking stoves (ICS) usage on self-reported eye irritation symptoms and respiratory health in the Northern Peruvian Andes. To identify the effect of ICS, we exploit field data related to the quasi-random distribution of ICS with faulty iron frames. Our results indicate that ICS long term usage, with an operative chimney, reduces respiratory illnesses and eye discomfort symptoms among housewives. It is also shown that in the case of respiratory health, other household members may benefit from reduced household air pollution (HAP) exposure. No health effects were found in households using the ICS without an operative chimney device, which suggest that reduced HAP is what drives our main results. Finally, this study also indicates that the household level factors influencing respiratory health significantly differ between male and female household members.

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1. Introduction

According to the Food and Agriculture Organization (FAO) nearly three billion people in the world rely on non-sustainable biomass energy sources[1]. This situation entails serious health risks, particularly in developing countries, given the close connection between biomass usage and the incidence of acute respiratory illnesses and chronic pulmonary diseases due to increased exposure to household air pollution (HAP) (Ezzati and Kammen (2002)). Furthermore, the World Health Organization (WHO) estimates that HAP from primitive household cooking is the leading environmental cause of mortality in the world, accounting for close to two million deaths annually (Martin *et al* (2011)).

In the last decades improved cooking stoves (ICS) have been extensively distributed in developing countries to decrease firewood consumption and alleviate forest degradation. As ICS have also the potential to reduce HAP exposure and as consequence improve respiratory health and wellbeing (some designs for example are installed with metallic chimneys), they have received increasing attention in the development literature. ICS usually outperform traditional biomass open fire stoves in controlled laboratory tests; however, its performance under real usage conditions is likely to considerably depart from what is observed in controlled settings (Hanna *et al* (2012)). In this sense, field based evidence is essential in order to assess the real performance of ICS.

In recent years, randomized control trials (RCTs) have been used to identify the health effects of ICS in the field. As in RCTs all individuals have the same ex-ante probability of being treated, treatment and control groups' have comparable means in expectations. The first field based RCTs evaluations on the health effect of ICS were performed in the context of the RESPIRE program, a RCT that distributed ICS in

Guatemala. The results in the RESPIRE related studies (see for example Diaz *et al* (2007) and Smith-Sivertsen *et al* (2009)) show a reduction in self-reported eye discomfort and respiratory symptoms within the first 12 to 18 months of ICS usage; however, no effect was found on objective health measures. An important limitation of the RESPIRE evaluation context is that the program fieldworkers were able to perform ICS maintenance and repairs within the evaluation timeline, which may distort beneficiaries' real usage and behaviour. More recently, Bensch and Peters (2015) exploit a RCT in Senegal, and find a significant reduction on women´s self-reported respiratory symptoms and eye discomfort after one year of ICS distribution. According to the authors, the study was performed in an unobtrusive way, and therefore captures real cooking behaviour.

The previous experimental studies evaluate the effect of ICS on health issues at early adoption stages. However, due to several reasons, it is also necessary to assess ICS performance in the long term. Firstly, medical research (Chapman *et al* (2005)) indicates that to identify a clear effect on self-reported symptoms related to chronic obstructive pulmonary diseases, a follow up of approximately 10 years would be required. Secondly, as in the case of the RESPIRE program; the presence of program fieldworkers at early adoption stages may distort beneficiaries' usage patterns, behaviour as well as self-reported outcomes. To the best of our knowledge, the only long term rigorous evaluation on the health impacts of ICS has been performed by Hanna *et al* (2012). Their results for a RCT in India indicate that people fail to use the ICS in the long term, and that ICS usage does not improve long term respiratory health. However, as Grimm and Peters (2012) stress out, this study presents several issues that limit its external validity. Particularly, the ICS distributed was a brick stove installed indoors, while cooking mostly takes place outdoors in the study area. Therefore, their results cannot be extended to contexts where cooking takes place in enclosed areas (as in the Peruvian Andes).

Our paper is the first one to provide evidence on the impacts of long term ICS usage on self-reported health for the Peruvian Andes (where cooking takes place indoors). It uses household data from the Chalaco District, where ICS were broadly distributed in 2003. To identify the causal effects of interest we exploit the haphazard distribution of faulty ICS in the intervention area, which influenced long term adoption. Our results indicate that using an ICS with an operative chimney decreases housewives' likelihood of reporting respiratory diseases and eye discomfort in the long term. Also, in the case of respiratory health, they suggest that other household members benefit from ICS usage. It is important to highlight that no effect on housewives health was found when a regression including only ICS users without an operative chimney was estimated, suggesting that reduced HAP is what drives our main results. The paper develops as follows: Section 2 briefly discusses the identification strategy, Section 3 presents the data, Section 4 analyses the empirical results, and finally Section 5 concludes.

2. Identification Strategy

In this paper we use the same identification strategy that we followed in Agurto (2013), which exploits the haphazard distribution of ICS with faulty iron frames during an ICS intervention in the Northern Peruvian Andes. This specific intervention distributed free of charge ICS with a metallic chimney (see figure 1) among the households in the Chalaco District in 2003. Approximately 84% of all households in the district received an ICS[2], and 95% of them were finally installed (Urday (2006)). According to the NGO in charge of the intervention, training related to stoves usage and basic maintenance was intensively provided during the distribution stages (Urday (2006))

As discussed in detail in Agurto (2013) and Agurto (2014), the monitoring reports carried within 8 to 12 after ICS distribution indicate that a proportion of beneficiaries that effectively used the new device experienced iron frame failures; and that close to 50% of these households stopped using the new cooking device. This evidence therefore suggests that iron frame failures influenced adoption. The monitoring reports also indicate that iron frame failures were not systematically caused by improper usage, maintenance or installation, but by faulty construction[3]. Also importantly, households could not to ex ante identify faulty stoves; and the NGO did not purposively allocated faulty stoves to any specific group or location. In addition to this, in Agurto (2013) we compare the main observable ex ante characteristics for a sample of beneficiaries using the ICS without problems and for those beneficiaries that reported an iron frame failure. The comparison confirms that the two groups were very similar in terms of their observable covariates[4].

To summarize, the evidence from the 2003 ICS intervention suggests that, conditional on adopting the new stove, experiencing an iron frame failure was uncorrelated to household characteristics. Then, to estimate the long term health effect of ICS usage with an operative chimney among adopters, in this paper we use an iron frame failure indicator as an instrument for ICS long term usage[5].

3. Data

In 2008 we implemented a household survey in the Chalaco District, in the Peruvian Andes, where ICS were distributed free of charge in 2003. The survey primary focus was on firewood consumption and ICS usage [6] patterns; however, we also gathered information related to respiratory health and eye discomfort. More precisely, the household head's spouse (or the most informed female member) was asked to identify all household members that suffered from respiratory diseases or bronchitis / eye irritation in the last 12 months. For the case of respiratory diseases, the enumerator provided the following examples: cough, phlegm and breathing problems[7]. We use the household's responses to these questions to estimate the effect of ICS long term usage on respiratory health and eye discomfort outcomes[8].

The use of self-reported health measures usually raises concerns in empirical studies. A first one is related to the possibility of individuals strategically misreporting their answers in order to influence decision makers. For example, non users may report a poor health status in order to obtain an ICS, or users may report an improved health status just to comply with the expectations of the intervention team. However, our study is not likely affected by this issue. In first place our sample only includes ICS beneficiaries (households that already received the stove in 2003), and households were completely unaware that the survey was intended to measure the impacts of the 2003 ICS intervention. Moreover, the health questions in the 2008 survey were asked before the ICS related ones; so even if the interviewed was able to set a connection between our survey and the 2003 intervention, the health answers were already reported. A second concern is related to the validity of self-reported health indicators as a measure of real health, given the possibility of measurement errors. Nevertheless, as Bensch and Peters (2015) clearly document, the literature supports the use of such indicators, as there is a close correlation between them and actual illnesses.

In the survey section related to ICS usage, households were asked if they received an ICS during the 2003 intervention, if they installed and made effective usage of it at some point in time, and if they were currently using the ICS as the main cooking device. Households that in the 2008 follow up reported using the ICS as the main cooking device were asked if they had to repair or change their ICS iron frame, which is directly connected to an iron frame failure. On the other hand, households that received, installed and initially used the ICS, but reported not using it in the 2008 survey, were asked for the main reason why they stopped using the device. Therefore, we are able to observe which ones stopped using the ICS due to an iron frame problem[9]. Using this information, we create an iron frame failure indicator. This indicator takes the value of one for non-users that stopped using their ICS due to an iron frame failure, and also for current users that experienced iron frame failures in the past (otherwise it equals zero).

It is important to mention that for some ICS users, the chimney was removed or completely destroyed (the majority broken or burned). As in this paper we aim to evaluate the effect of an ICS with a fully operative chimney as compared to traditional open fire stoves, we exclude this group of users from our baseline estimation sample[10]. Our final sample contains 384 individuals in 90 households within 19 villages. Given that the exogenous variation influencing long term ICS usage in our sample comes from faulty iron frames (and not chimney problems), excluding households that use the ICS but do not have an operative chimney does not invalidate our instrument. Moreover, it is important to emphasize that iron frames' and chimneys' production processes were not related at all; while the first ones were produced by different local workshops, the second ones were elaborated from standard, uniform, aluminum frames.

Table 1 reports the incidence of respiratory illnesses and eye discomfort symptoms in our sample. It shows that 31% of individuals reported being affected by respiratory diseases in the last 12 months, while only 15% reported eye discomfort symptoms. We can also observe that close to 1 in 3 housewives reported respiratory diseases and eye discomfort, while only 1 in 5 adult males reported respiratory diseases and only 1 in 7 adult males reported eye discomfort. Note also that approximately 1 in 2 infants (children 5 years old or younger) reported respiratory health problems.

(Table 1 here)

4. Empirical Results

4.1. Baseline OLS results

To estimate the effect of ICS usage with an operative chimney on self-reported health, we estimate the following baseline regression:

$$(1)\ R_{ihv} = \alpha_0 + \alpha_1 C_{hv} + \alpha_2 H_{ihv} + \alpha_3 C_{hv} \times H_{ihv} + \theta X_{ihv} + \beta Y_{hv} + V_v + e_{ihv}$$

In equation (1), R_{ihv} is a binary variable equal to one if individual "i" in household 'h" in village "v" suffered from respiratory diseases / eye discomfort in the previous 12 months (and zero otherwise). C_{hv} is our treatment variable, and equals one if the individual belongs to a household using an ICS with an operative chimney. H_{ihv} is a binary variable equal to one in the case of housewives, and $C_{hv} \times H_{ihv}$ is the interaction term between the treatment and housewife status. X_{ihv} and Y_{hv} are vectors of individual and household characteristics. The term V_v is a village fixed effect, while e_{ihv} is a random disturbance assumed to be correlated among individuals within the same household.

Following Angrist and Pischke (2009), we use a linear probability model to estimate the effect of ICS usage (reassuringly our probit estimates are similar to the OLS ones, and can be provided under request). Table 2 reports the results for the eye discomfort regressions. Column I in this table does not include an interaction term between ICS usage and housewife status. As it can be observed, the treatment coefficient (which captures the effect on any individual) is very small and not statistically significant. In Column II, an interaction term between ICS usage and housewife status is introduced. Here we report the total effect for housewives, the total effect for all other household members, as well as the difference between both groups' estimates (which is simply given by the interaction term in expression (1)). In this case, the effect of ICS usage on housewives is negative and statistically significant: housewives in households with an ICS are 18 percentage points less likely to suffer from eye irritation problems. On the other hand, the effect on other household members also appears as statistically significant, but has a positive sign and it is relatively small in size. The difference between the groups' point estimates is statistically significant and indicates that ICS usage only benefits housewives eye discomfort. In column III we allow for village fixed effects. Note that the treatment effect on housewives remains statistically significant and is slightly higher in absolute size than the effect obtained in Column II. On the contrary, the effect on other household members is not statistically significant and close to zero in size. The results in Column III also show that the difference between the groups' estimates is statistically significant, confirming that the effect on eye discomfort is only for housewives. Finally, column IV estimates a separate regression for housewives. The point estimate for the treatment effect is similar to those obtained in columns II and III; although it is not statistically significant (probably due to the reduction in sample size).

(Table 2 here)

Table 3 has the same structure as Table 2, and shows the results for the respiratory health regressions. Column I does not allow for an interaction term between the treatment and the housewife status dummies. As we can see, the effect of ICS usage (on any household member) appears to be negative; but it is not statistically significant in this specification. Column II includes an interaction term between the housewife and the ICS usage dummies. It shows that the effect of ICS usage is significant for housewives (at the 10% significance level); however, although the coefficient for the treatment effect on housewives is higher (in absolute value) than for others in the household, the difference between the estimates is not statistically significant. Colum III estimates a village fixed effects regression. In this case the ICS effect on housewives is statistically significant at the 1% significance level and relatively higher than the effect estimated in Column II. The effect of ICS usage on other household members is also statistically significant (at the 5% level), indicating that they also benefit from reduced HAP. As in column II, the point estimate for the treatment effect on housewives' in column III appears to be higher in absolute value than for other household members; however, the observed difference (given by the interaction term) is not statistically significant (due to our small sample we likely lack enough statistical power to reject the null of no difference between the groups' estimates). Finally, Column IV estimates a separate regression for housewives. The treatment coefficient for housewives in this regression is very similar to the ones we obtained previously; however, it is not statistically significant.

The finding that ICS usage only benefits housewives in the case of eye irritation and that the effect on respiratory health is probably higher for these individuals, likely reflects the fact that housewives are generally in closer distance to the stove during cooking tasks. In the other hand, our finding that ICS usage also benefits the respiratory health of other household members is likely related to the fact that in the Northern Peruvian Andes cooking takes place indoors, and the household stove is also used for heating purposes, particularly during the rainy season (December to May).

(Table 3 here)

4.2. Instrumental Variables

It is not possible to control for every individual and household factor that can be simultaneously correlated with ICS usage with an operative chimney and housewives' health (such as women's empowerment or unobserved ability). Moreover, it is important to point out that we are working with a reduced sample, and therefore are likely affected by sample selection problems. Therefore, our OLS results are not likely to capture the causal effect of ICS usage. To address for these issues, we use an iron frame failure indicator as an instrument for ICS usage. As discussed earlier, the allocation of faulty iron frames was quasi-random and unrelated to household characteristics.

Table 4 and Table 5 present the instrumental variables regressions results for the self-reported eye irritation and respiratory health regressions respectively. As we can observe, they confirm our previous findings. Table 4 shows that the treatment effect on eye discomfort is statistically significant only for housewives; while Table 5 indicates that the effect on respiratory health seems to be also statistically significant for other members in the household. Table 5 also shows that although the point estimate for the treatment effect on respiratory health seems to be higher in absolute size for housewives than for others, the difference is not statistically significant (likely as a result of not having enough statistical power). Note also that the point estimates for the treatment effects in Tables 4 and 5 are in all cases higher in absolute size than the OLS ones.

(Tables 4 and 5 here)

It is important to highlight that for the instrument to be valid, not only the random assignment condition must be satisfied, but the exclusion restriction should also hold. This means that having received a faulty iron frame should influence health only through ICS usage. In the case of our study, it is known that some ICS users that reported a faulty iron frame were able to repair it (others just obtained a new one from the NGO). Then, if repaired ICS are "substantially different" than those that did not present any problem (for example they may use more firewood), it is possible for iron frame failures to directly affect health, violating in this way the exclusion restriction. However, according to NGO members involved in the program, repaired ICS were able to perform in a very similar way as improved stoves without such deficiency[11]. The exclusion restriction will also be violated if people that experienced ICS failures tend to report poor health in order to obtain a new one. However we did not make any connection between our 2008 survey and the 2003 intervention and our health questions were asked before the ICS ones, so our results are not likely affected by this issue.

As we mentioned before, our paper aims to estimate the average treatment effect for housewives in households that received the ICS, installed it and decided to effectively adopt it as the main cooking device. However, in the presence of heterogeneity, endogeneity creates serious problems for identification of the population averages of interest. More precisely, in the presence of heterogeneity our instrumental variables approach provides us with a Local Average Treatment Effect (Imbens and Wooldridge, 2009). That is, it will be only informative about the average treatment effect on compliers: households who would keep making use of the ICS if they were allocated a good stove, and would stop using it if they were allocated a faulty one. For this to be true, the monotonicity assumption should be satisfied. This implies that there should not be individuals that would keep making use of the ICS if they were given a faulty iron frame and would stop making use of it if they were allocated a non-faulty one. We think that this is a reasonable assumption in our context of study.

4.3. Additional Estimations

4.3.1. Improved Cooking Stoves without and Operative Chimney

In Table 6 we only include in the user category housewives in households that reported using an ICS "without" an operative chimney. If a reduction in HAP is what drives the main results in Sections 4.1 and 4.2, there should not be any significant effect of ICS usage without an operative chimney on housewives' health outcomes.

(Table 6 here)

Column I in Table 6 estimates an OLS regression for the effect of ICS usage without an operative chimney on eye discomfort among housewives; while column II estimates the instrumental variable regression[12]. Columns III and IV are equivalent to columns I and II but focus self-reported respiratory health. As we can observe, the effect of ICS usage is not statistically significant in all columns, and although the coefficients have a negative sign, the point estimates are relatively low in absolute size[13]. These results suggest that decreased exposure to HAP is the basic channel through which ICS usage affects eye discomfort and self-reported respiratory health in this specific intervention in the Northern Peruvian Andes.

4.3.2. Stove Effect on Adult Males and Children

In sections 4.1 and 4.2, it was shown that the treatment variable only has a significant effect on eye discomfort among housewives; while in the case of respiratory health, there seems to be a significant effect on other household members. Tables 7 and 8 present the specific group regressions for the effect of ICS usage (with a chimney) on adult males (males older than 14 years old) as well as on individuals who are 14 years old or younger.

(Tables 7 and 8 here)

Table 7 presents the results for the effect of ICS usage on eye discomfort symptoms. Column I shows the OLS estimates for the effect of ICS only among adult males, while column II shows the corresponding instrumental variable regression. Columns III and IV are equivalent to columns I and II, but focus on individuals who are 14 years old or younger. As it can be observed, in all columns in Table 7 the effect of ICS usage is not statistically significant, but more importantly it is very small in absolute size.

Table 8 is equivalent to Table 7 but focuses on respiratory health. Note that for the instrumental variable results, the point estimates for the treatment effect on adult males and individuals 14 years old or younger is -0.29 and -0.32 respectively, and that the associated p-values are very close to 0.10 (in both cases they are equal to 0.13). From our perspective, the lack of statistical significance in this case is likely due to our small sample size; and therefore, the results in Table 8 suggest that other household members also benefit from reduced HAP. Also note that these estimates are lower in absolute size than the point estimate for the treatment effect on housewives in Table 5 (which equals -

0.38); however, the difference between the groups´ estimates is not statistically significant (also likely as a result of low statistical power).

4.3.3. Other Household Factors Related to Respiratory Health and Eye Discomfort

This section analyzes how other factors, included as controls in our previous regressions, are related to respiratory health and eye discomfort symptoms. Table 9 focuses only on housewives, while Table 10 focuses only on adult males. Columns I and II in Tables 9 and 10 present the results for the eye discomfort OLS and instrumental variables regressions respectively; whereas Columns III and IV present the estimation results for the respiratory health OLS and instrumental variables estimations correspondingly.

As it can be observed, in the case of eye irritacion, age is always statistically significant and positive. In other words, older male and female individuals are more likely to suffer from eye irritation problems. In the case of the respiratory health estimations, the age variable only has a positive sign for housewives, and its p-value is very close to 0.10 (the actual p-value is equal to 0.105). With respect to household's education (measured by the years of education of the adult member who attained the highest education), its coefficient is negative in the respiratory health regressions, however it is not statistically significant.

In the case of the number of rooms per household, this variable only has a significant effect on adult males' respiratory health; while the coefficient is not statistically significant and very small in absolute size in the housewives respiratory health regressions. This result suggests that for housewives, having a more spacious house does not make a significant difference (probably because they are already heavily exposed to HAP during cooking tasks); while adult males in a more spacious house may considerably benefit from reduced exposure to HAP (as they may be able to remain distant from the cooking area). The opposite pattern is observed when we focus on the presence of a child 11 years old or younger in the household. The coefficient for this variable in the adult males' respiratory health regression is small in size and not statistically significant; while for housewives this variable significantly increases the likelihood of suffering from respiratory illnesses. Probably because when young children are present, adult women stay longer at home, and are more exposed to HAP episodes.

5. Conclusion

To the best of our knowledge this is the first study on the health effects of long term ICS usage for the Andes Region. Our results confirms that ICS long term usage improves housewives' respiratory health and eye discomfort among households that decided to adopt the new cooking device, and that this effect is likely due to reduced exposure to HAP (no significant effect was found for housewives in households using an ICS without an operative chimney). The evidence also suggests that for the case of respiratory health, other members in the household benefit from ICS usage. This particular finding is likely related to the fact that in our study area cooking is carried indoors and the stoves are also used as a heating devices, particularly during the rainy season.

Given the health benefits of ICS usage, we expect that ICS will also have a positive impact on household's welfare due to fewer resources allocated to medical expenses as well as to increased productivity (due to improved health). Our results also indicate that the household level factors influencing exposure to HAP differ among different household members. For example, the presence of young children increases the likelihood of respiratory illnesses for women, but not for men; while having a more spacious house decreases the likelihood of respiratory illnesses only for males.

Our results are valid for contexts where firewood is the main source of cooking energy, and where cooking mostly takes place in enclosed spaces. They also point to the importance of facilitating access to ICS maintenance and repair in rural communities, as only ICS with operating chimneys positively affect health outcomes.

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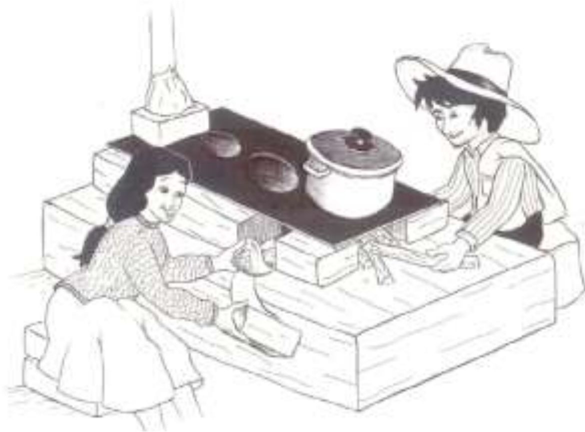
Figure 1: The ICS design in the Chalaco District



source: MIRHASPERU

Table 1: Respiratory Illnesses and Eye Discomfort Symptoms in the Chalaco District

	Incidence of self-reported respiratory illnesses	**Incidence of self-reported eye discomfort**
All Individuals (N=384)	0.32	0.15
Housewives (N=96)	0.30	0.32
Adult males (N=139)	0.22	0.13
Infants (≤5 years) (N=38)	0.46	0.02

Table 2: The effect of improved stove usage with an operative chimney on eye discomfort symptoms - OLS estimations

	I	**II**	**III**	**IV**
(1) Household uses an improved stove with an operative chimney: effect on all other household members	0.008 (0.032)	**0.072**** **(0.032)**	0.013 (0.037)	
(2) Household uses an improved stove with an operative chimney: effect on housewives		**-0.176**** **(0.088)**	**-0.234**** **(0.094)**	-0.170 (0.164)
Difference (2) – (1): ICS with a chimney* housewife status		**-0.248**** **(0.096)**	**-0.247**** **(0.099)**	
Village Fixed Effects	NO	NO	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.20	0.22	0.25	0.27
Observations	384	384	384	96

The dependent variable is the incidence of eye discomfort symptoms in the last 12 months. Observations in columns I to IV correspond to a total of 90 households in 19 villages. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy variable which takes the value of one if there is a household member 11 years old or younger. In columns I to III the standard errors are clustered at the household level; while in column IV standard errors are clustered at the village level. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels.

Table 3: The effect of improved stove usage with an operative chimney on respiratory health - OLS estimation

	I	**II**	**III**	**IV**
(1) Household uses an improved stove with an operative chimney: effect on all other household members	-0.107 (0.092)	-0.077 (0.096)	**-0.210**** **(0.095)**	
(2) Household uses an improved stove with an operative chimney: effect on housewives		**-0.187*** **(0.108)**	**-0.309***** **(0.107)**	-0.225 (0.167)
Difference (2) – (1); ICS with a chimney*housewife status		-0.108 (0.092)	-0.099 (0.084)	
Village Fixed Effects	NO	NO	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.08	0.08	0.23	0.39
Observations	384	384	384	96

The dependent variable is the incidence of respiratory illnesses in the last 12 months. Observations in columns I to IV correspond to a total of 90 households in 19 villages. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy variable which takes the value of one if there is a household member 11 years old or younger. In columns I to III the standard errors are clustered at the household level; while in column IV standard errors are clustered at the village level. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels.

Table 4: The effect of improved stove usage with an operative chimney on eye discomfort symptoms - Instrumental Variables estimation

Panel A: Second Stage Regressions				
	I	**II**	**III**	**IV**
(1) Household uses an improved stove with an operative chimney: effect on all other household members	-0.016 (0.043)	**0.094**** **(0.048)**	-0.011 (0.060)	
(2) Household uses an improved stove with an operative chimney: effect on housewives		**-0.286***** **(0.109)**	**-0.379***** **(0.119)**	**-0.493**** **(0.205)**
Difference (2) – (1): ICS with a chimney*housewife status		**-0.381***** **(0.127)**	**-0.369***** **(0.129)**	
Village Fixed Effects	NO	NO	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.20	0.21	0.24	0.21
Observations	384	384	384	96
Panel B -First Stage Regressions				
Instrumented Variable: Stove usage with an operative chimney				
Instrument: Iron frame failure	**-0.680***** **(0.032)**	**-0.760***** **(0.064)**	**-0.692***** **(0.059)**	**-0.676***** **0.072**
R2	0.58	0.59	0.71	0.79
Panel C - First Stage Regressions				
Instrumented Variable: Stove usage with an operative chimney * Housewife Status				
Instrument: Iron frame failure*housewife status		**-0.695***** **(0.067)**	**-0.700***** **(0.060)**	
R2		0.69	0.78	

The dependent variable is the incidence of eye discomfort symptoms in the past 12 months. Observations in columns I to IV correspond to a total of 90 households in 19 villages. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy variable which takes the value of one if there is a household member 11 years old or younger. In columns I to III the standard errors are clustered at the household level; while in column IV standard errors are clustered at the village level. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels.

Table 5: The effect of improved stove usage with an operative chimney on respiratory health - Instrumental Variable estimations

	I	II	III	IV
Panel A: Second Stage Regressions				
(1) Household uses an improved stove with an operative chimney: effect on all other household members	-0.168 (0.123)	-0.137 (0.136)	**-0.318**** **(0.142)**	
(2) Household uses an improved stove with an operative chimney: effect on housewives		**-0.242*** **(0.129)**	**-0.426***** **(0.132)**	**-0.386**** **(0.170)**
Difference (2) – (1): ICS with a chimney*housewife status		-0.104 (0.113)	-0.109 (0.105)	
Village Fixed Effects	NO	NO	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.07	0.08	0.22	0.36
Observations	384	384	384	96
Panel B -First Stage Regressions				
Instrumented Variable: ICS usage with an operative chimney				
Instrument: Iron frame failure	**-0.680***** **(0.032)**	**-0.760***** **(0.064)**	**-0.692***** **(0.059)**	**-0.676***** **0.072**
R2	0.58	0.59	0.71	0.79
Panel C - First Stage Regressions				
Instrumented Variable: ICS usage with an operative chimney * Housewife Status				
Instrument: Iron frame failure* housewife status		**-0.695***** **(0.067)**	**-0.700***** **(0.060)**	
R2		0.69	0.78	

The dependent variable is the incidence of respiratory illnesses in the last 12 months. Observations in columns I to IV correspond to a total of 90 households in 19 villages. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms, per capita value of farm assets, and a dummy variable which takes the value of one if there is a household member 11 years old or younger. In columns I to III the standard errors are clustered at the household level; while in column IV standard errors are clustered at the village level. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels.

Table 6: The effect of ICS usage without an operative chimney on housewives' eye discomfort and respiratory health

	Eye discomfort		Respiratory Health	
	I	**II**	**III**	**IV**
Panel A	**OLS**	**Instrumental Variables (2nd stage)**	**OLS**	**Instrumental Variables (2nd stage)**
Household uses an improved stove without an operative chimney: Effect on Housewives	-0.085 (0.144)	-0.078 (0.155)	-0.065 (0.101)	-0.127 (0.108)
Village Fixed Effects	YES	YES	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.24	0.24	0.27	0.26
Observations	125	125	125	125
Panel B		**1st Stage**		**1st Stage**
Instrument 1: Iron frame failure		**-0.702***** **(0.059)**		**-0.702***** **(0.059)**
R2		0.67		0.67

The dependent variable in columns I and II is the incidence of eye discomfort symptoms in the last 12 months. The dependent variable in columns III and IV is the incidence of respiratory illnesses in the last 12 months. The odd columns estimate an OLS regression, and the even columns estimate an IV regression. All columns control for age, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy which takes the value of one if there is a household member 11 years old or younger. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels. Standard errors have been clustered at the village level.

Table 7: The effect of improved stove usage with an operative chimney on eye discomfort symptoms - Adult males and children specific group regressions

	Adult males		14 years old or younger	
Panel A	**I**	**II**	**III**	**IV**
	OLS	**Inst. Var. 2nd Stage**	**OLS**	**Inst. Var. 2nd Stage**
Household uses an improved stove with an operative chimney: Effect on adult males	-0.009 (0.091)	0.061 (0.120)		
Household uses an improved stove with an operative chimney: Effect on household members age≤14			0.011 (0.056)	0.130 (0.129)
Village Fixed Effects	YES	YES	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.26	0.25	0.17	0.13
Observations	139	139	133	133
Panel B		**1st Stage**		**1st Stage**
Instrument: Iron Frame Failure		**-0.609***** **(0.056)**		**-0.569***** **(0.075)**
R2		0.81		0.58

The dependent variable is the incidence of eye discomfort symptoms in the previous 12 months. The odd columns estimate an OLS regression, and the even columns estimate an IV regression. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy which takes the value of one if there is a household member 11 years old or younger. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels. Standard errors have been clustered at the village level.

Table 8: The effect of improved stove usage with an operative chimney on respiratory health - Adult males and children specific group regressions

	Adult Males		14 years old or younger	
Panel A	**I**	**II**	**III**	**IV**
		Inst. Var. 2nd Stage		**Instr. Var. 2nd Stage**
Household uses an improved stove with an operative chimney: Effect on adult males	-0.146 (0.111)	-0.294 (0.196)		
Household uses an improved stove with an operative chimney: Effect on household members age≤14			-0.255 (0.193)	-0.318 (0.212)
Village Fixed Effects	YES	YES	YES	YES
Individual and Household controls	YES	YES	YES	YES
R2	0.31	0.31	0.25	0.24
Observations	139	139	133	133
Panel B		**1st Stage**		**1st Stage**
Instrument: Iron frame failure		**-0.609***** **(0.056)**		**-0.569***** **(0.075)**
R2		0.81		0.578

The dependent variable is the incidence of respiratory health illnesses in the previous 12 months. The odd columns estimate an OLS regression, and the even columns estimate an IV regression. All columns control for age, sex, years of education of the adult household member with the highest level of education, number of rooms per capita, per capita value of farm assets, and a dummy which takes the value of one if there is a household member 11 years old or younger. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels. Standard errors have been clustered at the village level.

Table 9: Housewives' eye discomfort and respiratory health: individual and household level controls

Dependent variable:	Eye Discomfort		Respiratory health	
	I	II	III	IV
	OLS	Int. Var.	OLS	Int. Var.
Age	**0.010*** (0.003)**	**0.008*** (0.003)**	0.005 (0.003)	0.004 (0.003)
Years of Education of the Household Member with the Highest Education	0.002 (0.019)	0.004 (0.018)	-0.030 (0.018)	-0.029 (0.018)
Household's per capita wealth (value of farm assets in 2008 Peruvian soles)	-0.000 (0.001)	0.000 (0.001)	0.001 (0.001)	0.001 (0.001)
Household's Number of Rooms per capita	-0.082 (0.146)	-0.099 (0.149)	0.016 (0.139)	-0.008 (0.124)
Household has a member 11 years old or younger (yes=1)	-0.053 (0.149)	0.019 (0.155)	**0.226** (0.092)**	**0.255** (0.107)**
Observations	96	96	96	96

The dependent variable in columns I and II is the incidence of eye discomfort symptoms in the last 12 months. The dependent variable in columns III and IV is the incidence of respiratory illnesses in the last 12 months. The odd columns estimate an OLS regression, and the even columns estimate an IV regression. Columns I and II show the coefficients for the individual and households controls corresponding to column IV in tables 2 and 4, while columns III and IV show the coefficients for the individual and households controls corresponding to column IV in tables 3 and 5. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels. Standard errors have been clustered at the village level.

Table 10: Adult Males' eye discomfort and respiratory health: individual and household level controls

Dependent variable:	Eye Discomfort		Respiratory health	
	I	II	III	IV
	OLS	Int. Var.	OLS	Int. Var.
Age	**0.006*** (0.002)**	**0.006*** (0.002)**	-0.003 (0.002)	-0.003 (0.002)
Years of Education of the Household Member with the Highest Education	-0.007 (0.014)	-0.006 (0.014)	-0.017 (0.010)	-0.013 (0.014)
Household's per capita wealth (value of farm assets in 2008 Peruvian soles)	**0.001** (0.000)**	**0.001** (0.000)**	0.001 0.001	0.001 0.001
Household's Number of Rooms per capita	-0.062 (0.081)	-0.062 (0.079)	**-0.198* (0.097)**	**-0.184* (0.098)**
Household has a member 11 years old or younger (yes=1)	0.005 (0.074)	-0.015 (0.080)	0.148 (0.109)	0.189 (0.111)
Observations	139	139	139	139

The dependent variable in columns I and II is the incidence of eye discomfort symptoms in the last 12 months. The dependent variable in columns III and IV is the incidence of respiratory illnesses in the last 12 months. The odd columns estimate an OLS regression, and the even columns estimate an IV regression. Columns I and II show the coefficients for the individual and households controls corresponding to columns I and II in table 7, while columns III and IV show the coefficients for the individual and households controls corresponding to columns I and II in tables 8. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significance levels. Standard errors have been clustered at the village level.

[1] http://www.fao.org/bioenergy/67564/en/

[2] By 2003 the total number of households in the Chalaco district was approximately 2000.

[3] The monitoring reports indicates that in only 17% of the cases with materials problems, also installation deficiencies were detected; and that in only 25% of the cases with material problems, excessive use of firewood was reported. Furthermore, from all the households reporting excessive firewood usage, only 20% reported materials problems, and from all the cases in which an installation deficiency was detected, only 28% reported materials problems (MIRHASPERU – Universidad de Piura internal report 2004).

[4] We refer the reader to Table 1 in Agurto (2013).

[5] We asked approximately half of the households that reported an iron frame failure if we could take a look at their iron frames, and in almost all cases we were able to visually confirm the presence of such failures.

[6] It is important to highlight that firewood stoves are the main devices used for cooking and heating purposes in the area, with only 3% of the households reporting usage of gas or kerosene stoves.

[7] However, when registering the answer to the question, we did not distinguished between the different symptoms.

[8] As the survey questions ask for the incidence of such illnesses in the last 12 months, a few households that stopped using the ICS within a year before the interview have to be excluded from the estimations.

[9] While current users were directly asked if they experienced a problem with the iron frame; unfortunately, non-users were asked in a general way for the main reason why they stopped using the stove; then, for those non-users that did not report iron frame problems we are not able to observe whether they were allocated a faulty iron frame or not. However, it is important to highlight that non-users that stopped making use of their stove due to a problem other than an iron frame failure seem to have made use of the stove for a short period of time. Our data indicates that nearly 50% of these non-users reported using the stove for 6 months or less; which may not be enough usage time for the material problem to reveal. In the case of non-users that reported material problems, the proportion that made use of the improved stove for less than 6 months was very small, lower than 15%, which suggests that these group of households decided to adopt the stove as the main cooking device (and were then "forced" to stop using it due to an exogenous reason: an iron frame failures). In this sense, our sample is representative of those households that decided to adopt the improved stove in the long term, some of which received a faulty ICS.

[10] When we include all ICS users in the sample and we estimate the average effect of "using the improved stove" (whether with a properly working chimney or not), the OLS and IV results point in the same direction as to the ones presented in the paper, in which users without a chimney have been excluded from the baseline estimations. Compared to the results in the paper, the coefficients that we obtain when we include all users in the treatment category are relatively smaller, which is expected, as some of these users operate the stove without a chimney device (in section 4.3.1 in the paper we compare users without the chimney with users of traditional open fire stoves, and show that there is no ICS effect in this case).

[11] To provide evidence on the fact that a repaired stove performs in a very similar way than a stove of good quality, we estimated a regression including only current users of the improved stove (results not shown), in this regression firewood consumption is the dependent variable and we control for whether the household experienced an iron frame problem (which should be exogenous); the results indicate that having experiencing an iron frame failure does not have any significant effect.

[12] The results are very similar in the regression that includes all household members and uses interaction terms between the member status and improved stove usage to capture the improved stove effects.

[13] No effects were also found in the case of other members in the household.