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ABSTRACT

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Local beer breweries in Burkina Faso absorb a considerable amount of urban woodfuel demand. We assess the woodfuel savings caused by the adoption of improved brewing stoves by these, mostly female owned, small enterprises and estimate the implied welfare effects through the woodfuel market on private households. We find substantial wood savings among the breweries and, subsequently, huge welfare gains for households. Since woodfuel is predominantly used for cooking by the poorer strata, the intervention under study is an example for a green growth intervention with pro-poor welfare gains – something green growth strategies should look for.

JEL Classification: D2, D6, I3, O3

Keywords: demand for woodfuel, technology adoption, improved stoves, green growth, impact evaluation, female employment

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1. Introduction

Poverty and environmental hazards are directly related. One of the most striking examples for this is the usage of biomass – mostly firewood and charcoal – for cooking purposes. More than 3 billion people rely on such fuels, because modern cooking fuels like electricity or gas are not affordable or accessible. The provision of woodfuels is associated with a heavy burden for the users. In rural areas where firewood is mostly collected, it induces a substantial work load, in urban areas where charcoal or firewood must be bought, it induces a heavy monetary burden. In addition, the wood extraction and the combustion in mostly very inefficient cooking devices have severe environmental implications (see Pant et al. 2014, Martin et al. 2011). First, on the local level the bad combustion process leads to smoke emissions that contain harmful pollutants killing 4.3 million people every year according to the World Health Organisation (WHO, 2012). On the regional level, biomass usage contributes to deforestation and forest degradation. On the global level, burning biomass leads to climate relevant emissions, most notably CO2 and black carbon.

Combating such environmental deficits is high on the agenda of international cooperation and national governments. The idea of putting developing countries on an environmentally more sustainable trajectory has made inroads into the rhetoric of aid agency as *green growth*. In a recent paper, Stefan Dercon (Dercon, 2014) challenges the green growth concept by emphasizing that "curbing environmental damage now […] means diverting resources from other conventional growth-oriented opportunities". Thereby, the trade-off between the alleviation of current poverty and achieving intergenerational equity is put into the focus. While Dercon clearly acknowledges that not internalizing environmental costs today might lead to future poverty, the high discount rates of today's poor and "their dire circumstances leave little room for the use of long planning horizons". In a nutshell, Dercon asks to what extent green growth is actually good for today's poor. Three green growth strategies are identified: First, internalizing externalities by changing prices, second, investments in environmentally less damaging production processes, for example energy efficiency enhancements, and, third, climate change adaptation investments.

In this paper, we provide evidence to this debate by examining the impacts of an energy efficiency intervention in Burkina Faso – called FAFASO – and the repercussions it has on the urban poor. The energy efficiency intervention endows local beer breweries in the two major cities of Burkina Faso with improved brewing stoves. Local beer breweries in Burkina Faso absorb a considerable amount of urban woodfuel demand – more than 50% according to the Burkinabè Ministry of Environment. At the same time, virtually all private households rely on woodfuels for their daily cooking purposes with wood being a scarce and hence highly priced good in Sahelian Burkina Faso where deforestation advances at a rapid pace.[1] While the policy intervention under evaluation is a classical green growth intervention that focusses on energy consumption in enterprises, we evaluate not only the direct effects this has on the firewood consumption and CO2 emissions, but also the indirect effects on households: Since firewood unlike other climate relevant energy sources is traded on local markets only, drastically changing demand patterns can be expected to affect the prices the urban poor pay for a good they use on a daily basis.

Our analysis is based on two original data sets that we collected among local beer breweries and households in Ouagadougou and Bobo Dioulasso. The survey of 261 local beer breweries was conducted in September 2012. These local beer breweries are micro-enterprises virtually always run by women, the so-called dolotières. The consumption of the local beer, the dolo, as well as the craft of brewing it is deeply entrenched in the Burkinabè culture. It is usually modestly consumed, but on a very regular basis and by most Burkinabè. The brewing process is very energy and labour intensive and rather an artisanry than an industrial process. Our 2012 dolotières survey is complemented by a first wave of interviews among 219 dolotières of whom 88 are among the 261 interviewed in 2012. The first wave of data collection was conducted by IRSAT, an Ouagadougou based research institute, in 2010, i.e. before the intervention was implemented. The second dataset we use is a survey among 892 households in Ouagadougou that we conducted in December 2010. It contains unique information on cooking relevant issues including firewood and charcoal demand.

We use these two datasets to examine the effectiveness of the energy efficiency intervention and, subsequently, the effects it has on wood consuming households. As a first step, we examine the determinants of up-take of improved brewing stoves. Second, we estimate the wood savings associated with the use of an improved brewing stove. Third, we evaluate the implied welfare effects on private households resulting from a reduced price for wood and charcoal under actual and hypothetical adoption rates. Given that poorer households spend a larger share of their budget on cooking fuels than richer ones, reducing the price of woodfuel should be particularly pro-poor. Fourthly, we explore the environmental impact associated with reduced deforestation.

[1] Forest coverage in the country has decreased from 68,500 sq km in 1990 to 55,300 sq km in 2012 (WDI 2014).

To our knowledge, this paper is the first to examine woodfuel consumption in micro-enterprises and the second-round effects of an energy efficiency intervention targeting woodfuel consumption. Our paper is related to the large literature on improved stoves for cooking (see e.g. Pant et al. 2014, Smith-Sivertsen et al., 2009; Yu, 2011; Hanna et al., 2012; Bensch and Peters, 2013, 2014) that usually focuses on health and environmental impacts as well as direct effects on energy expenditures, but that does not examine indirect effects on prices. Our paper also contributes to the literature on innovation and technology adoption in a context in which credit and insurance markets are incomplete and returns from innovation might be uncertain (see e.g. Foster and Rosenzweig, 1995; Blackman and Bannister, 1998; Bandiera and Rasul, 2006; Conley and Udry, 2010; Duflo et al., 2011). The paper is also related to the literature that explores the distributional impacts of food price inflation and the inflation of other goods that particularly matter for poor households (see e.g. Prais, 1959; Deaton, 2003; Günther and Grimm, 2007; Wodon et al., 2008). Finally, the paper contributes to the literature on the role of woodfuels for deforestation and the implied economic costs (see e.g. Ribot, 1999; Arnold et al., 2006).

The remainder of the paper is organized as follows. In the next section we provide background information about the business of making 'dolo' and the stove intervention under study. In Section 3, we present our data. In Section 4 we explain how we assess direct savings for breweries, the indirect welfare effects for wood-consuming households and the environmental impact. Section 5, we first analyze adoption and then present the results for the three types of impacts. In Section 6 we conclude.

2. The business of making 'dolo' and the 'FAFASO' intervention

FAFASO is implemented by the GIZ under the umbrella of the Dutch-German energy partnership 'Energising Development' (EnDev). FAFASO, targets three types of actors: households, social institutions, such as schools and health centres, and microenterprises. We focus on improved cooking stoves for local beer breweries. The FAFASO intervention differs from other earlier improved cookstove (ICS) promotion programmes in Burkina Faso mainly because it does not provide direct subsidies. Instead, it rather focuses on the training of ICS producers (whitesmiths, potters and masons), sensitization, and marketing campaigns. FAFASO started in 2005 to promote ICS in two cities, the capital, Ouagadougou and Bobo-Dioulasso, Burkina Faso's second largest city. Initially the program started with cooking stoves for private households. In 2008 the GIZ started to train masons in constructing special stoves for dolo breweries that are designed to curb firewood consumption in the brewing process, since the production of dolo needs a lot of energy, typically firewood, because once the basis of the beer, the sorghum, is crushed and ground into a paste (malt), it needs to be boiled for more than a day. The training of masons was first concentrated in communities in the Eastern region of the country and was implemented in collaboration with dolo producer associations. From 2008 onwards such trainings were repeatedly organized. In Ouagadougou and Bobo-Dioulasso, these trainings started in 2010 (in Bobo-Dioulasso six months later than in Ouagadougou). This was accompanied by sensitization campaigns among dolo producers in both cities and in the rural communities around Ouagadougou and by the installation of test stoves in breweries where the dolotières had some model or leader-role (‘*femme leader*’). Further masons were trained in the Centre-Est region.

Table 1 shows the number of installed Dolo stoves in 2010, 2011 and 2012. The number of installations peaked in 2010 in the regions ‘Sud-Ouest’ and ‘Est’ and in 2011 in Ouagadougou and Bobo-Dioulasso. In 2012 the number of installations decreased significantly. By the end of 2012, 2,317 stoves had been installed. The decline from 2012 onwards might be due to market saturation. The early awareness campaigns by the FAFASO seem to have been quite successful, so that by 2012 maybe all those that had made plans to invest in such a stove had already bought one.

[please insert Table 1]

The improved cooking stoves made for breweries – ‘Roumdé stoves’ hereafter - are much larger than the household cooking stoves and are made of clay and bricks rather than metal.[2] These stoves are fixed and typically comprise between two and five huge cauldrons (although different sizes exist), the so-called ‘marmites’ (if made of aluminium) or ‘canaris’ (if made of clay). Aluminium is more widespread in Ouagadougou and clay in Bobo-Dioulasso. In front is an always-open door to the combustion chamber through which the firewood is loaded; typically by using entire trunks of wood that are by and by moved into the oven. A typical stove easily spans the surface of three to four square metres with the cauldrons arranged symmetrically over this space. In contrast traditional stoves basically consist of a set of cauldrons that is lifted by a few bricks allowing moving firewood under the cauldrons. Some slightly modified versions of these traditional stoves exist, which have some

[2] “Roumdé” is the brand name chosen by the GIZ. Roumdé means “the preferred” in the national language Mooré.

sort of combustion chamber, but are not of the same quality than the Roumdé. Both the Roumdé and two traditional stoves are shown in Figure 1.

[please insert Figure 1]

A Roumdé costs about CFA F 27,500 (or EUR 42, official exchange rate used)[3] without the cauldrons. Aluminium cauldrons (marmite) cost depending on the size between CFA F 20,000 (EUR 30) and CFA F 60,000 (EUR 90) and are hence more expensive than the Roumdé it-self and much more expensive than clay cauldrons, but they also have a much longer life-span than the latter. Cauldrons made of clay often crack if the stove is overheated. Aluminium cauldrons can in principle melt, but it seems that this happens only very rarely. Because changing the cauldrons with a Roumdé is also expensive, since the upper mantle of the stove needs to be opened, some dolotières switch from clay to aluminium when they buy a Roumdé.

According to the GIZ a Roumdé saves at least 60% to 70% of the firewood needed with a traditional stove for one brewing process. However, it seems that the saving rate goes rapidly down if the improved stove is poorly maintained. In one field test conducted by the Institut de Recherches en Sciences Appliquées et Technologies (IRSAT) a damaged improved stove even needed more firewood per litre of dolo than a traditional stove (Sanogo et al., 2011), confirming that a rigorous assessment of the effectiveness of such stoves requires a test under real world conditions where conditions include the quality status of the stove and how the stove is used.

Making dolo is a tradition. The activity is exclusively done by women (the so-called “dolotières”), typically Christian or animist, since Muslim women are not allowed to make alcohol. The alcohol arises once the boiling of the malt is done. By adding yeast and by letting it ferment, the beer – dolo – is produced. When the dolo is ready, the women typically fill up big plastic barrels of it. They then sell either directly to customers or to other retailers. For the customers, most dolotières have a so-called cabaret, typically some benches to a shady spot outside the courtyard. Usually, the cabaret scene is geared towards simple socializing. Excessive drunkenness is rare. People start passing through around eight or nine in the morning, on their way to work. Others come during the day or on their way back from work. Those who consume in the cabaret drink it from a so-called ‘calabashe’. For take-away the breweries usually use empty soda bottles or plastic containers. A litre bottle of dolo is sold for about CFA F 150 (EUR 0.23). In urban areas the typical brewery is located in a backyard has

[3] Note that in 2010 PPP, the price of a Roumdé is roughly EUR 157.14 (Penn World Tables version 7.1).

one or several stoves, additional cauldrons and barrels to stock raw materials, intermediate outputs, residuals and the final product, the dolo. Wood is stocked at the side or outside the yard. The piles of wood can be relatively large, since most breweries purchase wood for several brewings.

3. Data

We use three different types of data: (i) dolo breweries survey data, (ii) information drawn from focus group discussions, in-depth interviews with stakeholders and other experts and field visits and (iii) household data on cooking behaviour. In what follows we briefly present each source.

3.1. Survey data on dolo breweries

In 2010 the *Institut de Recherches en Sciences Appliquées et Technologies* (IRSAT) conducted a census to count all dolo breweries in greater Ouagadougou and Bobo-Dioulasso, i.e. including their surrounding (rural) villages. The census revealed that in and around Ouagadougou 2,397 breweries were operating. In and around Bobo-Dioulasso the count was 1,144 breweries (Sanogo et al., 2011). Because the census had been conducted at the end of the rainy season and some breweries temporally close in that period of the year, the actual number might even be a bit higher.

From this list of breweries, IRSAT then randomly selected 219 breweries - 158 in and around Ouagadougou and 61 in and around Bobo-Dioulasso. With the help of a dolo producers association, the selected breweries were then contacted and interviewed. Our questionnaire collected information about the socio-demographic characteristics of these breweries and the people working there, the brewing process including wood consumption and about the awareness and possibly use of improved cooking stoves. This information was used by IRSAT to produce a report commissioned by the GIZ to better target and design the FAFASO activities, in particular the promotion of improved stoves for breweries that only started in 2010 (Sanogo et al., 2011).

In September 2012, i.e. exactly two years later, we tried to re-interview as many as possible breweries from the 2010 sample and to add, depending on the experienced attrition, new breweries. Hence, in total 261 breweries, 178 in and around Ouagadougou and 83 in and around Bobo-Dioulasso,[4] were visited and interviewed. The interviews were conducted by staff from IRSAT again with support from the association of breweries. Attrition turned out to be quite high. From the 261 breweries, 88 had already been interviewed in 2010. Many of the breweries visited in 2010 refused to participate again in the survey, some were not present the days the interviewers came and again others had stopped their activity, either temporally or definitely. Absence was often due to the fact that during this period of the year labour is needed for harvesting. New breweries were randomly drawn from the list of all breweries registered through IRSAT's census. Table 2 documents the sample compositions in 2010 and 2012.

[please insert Table 2]

The questionnaire used in 2010, had been enriched by a number of additional questions allowing better to scrutinize the impact of improved stoves on wood consumption. Information on and related to wood consumption was only incompletely collected in 2010. In particular, information related to the stoves in use were asked separately for every stove such as the type of the stove, its condition, its age, its price, the number of cauldrons, the material of the pots and their size. The questionnaire included also more questions about the use of inputs and the awareness of and attitudes towards improved stoves. The questionnaire had been tested in the field prior to the survey. Table 3 presents some basic statistics of the interviewed owners of the breweries. As indicated above, dolo is almost exclusively produced by women and hence in our sample are also only women. They are on average around 45 years old. Only a quarter of them have completed primary school. Two-thirds belong to the ethnic group of the Mossi. The remaining third belongs to the group of Bobo, the dominant group in Bobo-Dioulasso. In 2012, 30% of all breweries interviewed were located in rural areas, i.e. outside of the city in one of the neighbouring villages. Most respondents are already for a long time in business, 15 years on average. Overall, the distribution of the characteristics is very stable between 2010 and 2012, suggesting that the sampling of new breweries to replace the drop-outs did not reduce the representativeness of the sample.

[please insert Table 3]

Obviously, wood consumption is the central outcome in this study. Ideally, it would be measured by weighing the actual amount of wood used per brewing. Given the large quantities of wood involved and the long duration of the brewing process, we decided to ask

[4] Regarding Bobo-Dioulasso it is important to note that by the time the survey was conducted no FAFASO activities had been taken place in the rural communities of Bobo-Dioulasso.

the dolotières to provide an estimate of the value of consumed wood. Local experts from IRSAT were confident that the dolotières know very well how much they consume and indeed as will be seen below, the provided information satisfies a number of plausibility checks suggesting that measurement error and in particular systematic (i.e. non-classical) measurement error is not a major issue. In fact breweries buy their wood very regularly and hence seem generally to have a good feeling of how much wood they use.

Table 4 presents some descriptive statistics, now only based on the 2012 survey for which the information has been elicited in more detail. We show the characteristics separately for Ouagadougou and Bobo-Dioulasso and for Bobo-Dioulasso also separately for the city, as only there FAFASO has been active. Breweries in Ouagadougou have on average 1.8 stoves. Breweries in Bobo-Dioulasso are somewhat smaller. In Ouagadougou 0.8 stoves, i.e. less than 50% of these stoves are Roumdé stoves. In Bobo-Dioulasso only 0.3 stoves are Roumdé stoves, i.e. less than 25%. However, if the count is limited to the city of Bobo-Dioulasso, the average number is 0.8, which is then more than 50%. In Ouagadougou and Bobo-Dioulasso respectively 0.85 and 0.42 stoves fall into the category 'improved traditional stoves' (0.62 in Bobo-Dioulasso city). 38% of the Ouagadougou sample and 17% of the Bobo-Dioulasso sample use only a Roumdé. Stoves in Ouagadougou typically have four cauldrons, in Bobo-Dioulasso even five or six. Whereas in Ouagadougou aluminium cauldrons are more common; in Bobo-Dioulasso clay cauldrons are more frequently used. In Bobo-Dioulasso the common view among consumers is that dolo beer only has its authentic taste if it is brewed in clay cauldrons. The reported age of the stove (not necessarily the cauldrons) is relatively high, more than eight years on average, in Bobo-Dioulasso even a bit more. The enumerators classified most stoves as being in a good condition, in particular in Bobo-Dioulasso; some have cracks or a broken door, and only few are really shabby. Doors typically break when complete trunks of trees are little by little moved into the stove. Moreover, the high temperature that is achieved with a stove damages the cauldrons. Another typical cause of damage is rain and dogs that search protection in the stoves when not in use. Their scraping damages the inner mantle of the stove. However, given the simplicity of traditional stoves, they are also less subject to obvious damages and, hence, their quality is very often reported to be good.

[please insert Table 4]

Most breweries brew twice a week. The average brewing is much larger in Ouagadougou compared to Bobo-Dioulasso. In Ouagadougou almost 370 litres are produced with one brewing. This requires as input about 85kg of malt and 7 barrels of water. The water-malt ratio determines the quality of the beer and also has an important influence on the required quantity of wood. In Bobo-Dioulasso many breweries produce their own malt and use less water; hence their beer has a higher concentration compared to the beer produced in Ouagadougou. The average brewery in Ouagadougou has a monthly turnover of about EUR 500 to EUR 1,000 (assuming that a litre of dolo is sold at CFA F 100 to 200). Wood and other intermediate inputs account for about EUR 200, such that the average value added that is generated is in the context given quite remarkable, even if the variance around the mean is substantial.[5]

On average, a brewing in Ouagadougou requires wood of a value of about CFA F 8,957 (or EUR 13.70) or CFA F 24.2 per litre of dolo.[6] In Bobo-Dioulasso we find an average of CFA F 25 per litre (CFA F 34 per litre in Bobo-Dioulasso city).[7] Beyond possible efficiency differences, there are at least two additional factors affecting the cost per litre: On the one hand, wood is a bit cheaper in Bobo-Dioulasso compared to Ouagadougou. On the other hand, breweries in Bobo-Dioulasso use different stoves and cauldrons and buy, as can be seen at the end of Table 3, more frequently their wood in smaller quantities, which typically means they have to pay a higher unit price compared to a larger purchase. In Ouagadougou about 32% of all breweries get their wood by truck and hence have typically a huge pile of wood they take from. One reason why breweries decide to buy in small quantities despite the higher price is that this prevents, at least in the rainy season, the wood from getting wet. Surprisingly, even the larger breweries, that systematically buy huge piles of wood, very often do not have a roof to protect their wood from humidity. In the rural part of Bobo-Dioulasso, some of the smaller breweries still collect or cut their own wood (8% of all breweries surveyed).

3.2 Focus group discussions, expert interviews and field visits

To complement the information drawn from the representative survey, we undertook intensive field work before and after the implementation of the brewery survey. Prior to the brewery survey, we interviewed the GIZ staff managing the project, project collaborators, a group of trained masons and a dolo producer association. Moreover, we visited more than ten

[5] The survey did not directly ask for turnover, value added or profits as most dolotières would not accept to give an answer or, at least a 'correct' answer. Hence, these numbers are simply derived from the information about the quantity of dolo produced, the average price per litre and the information about some cost categories.

[6] Not counting those breweries that collect their fire wood and hence have not declared any wood expenditure.

[7] Please note the consistency in these estimates. If the data was plagued by systematic errors, one would not expect such stable figures.

breweries in Ouagadougou and Bobo-Dioulasso for in-depth interviews. The gathered information allowed getting a better understanding of the organization and process of dolo production, to adequately design the questionnaire of the survey and to enrich and complement the results from the quantitative impact assessment based on the survey data.

3.3 Survey data on woodfuel consuming households

To illustrate the welfare effects that arise for woodfuel consuming households as a consequence of a reduced price for woodfuel, we use data from a specific household survey that we conducted between February and March 2011 in Ouagadougou and Bobo-Dioulasso (Bensch et al., 2014). Here we just use the sample for Ouagadougou which covers 892 households. This sample is representative for the population of Ouagadougou except the roughly five percent richest households. The surveys main purpose was to assess the effectiveness of improved cook stove use among private households. The dataset includes information about total expenditure per capita and expenditure per capita for wooduels, cooking energy and energy as a whole. Woodfuel consumption used for cooking – wood and charcoal – was also measured in quantity. Households were asked to specify and show the amount of fuel used with that particular dish, which the enumerators who were equipped with weigh scales weighed then. In combination with information collected on the number and type of dishes cooked per week, the weekly wood consumption can be determined.

4. Methodological issues and theoretical thoughts

Our assessment will focus on three types of effects. First, reduced wood consumption and hence reduced production costs for dolo breweries; second, a reduced price of fuel wood for consumers of household cooking energy; and, third, an environmental benefit through reduced deforestation and lower CO2 emission. In what follows we explain very briefly how we account for each of these three effects.

4.1 Direct effects on breweries

To provide an assessment of the direct benefits accruing to Roumdé users, we focus on woodfuel savings per litre of dolo brewed and changes in monthly profits. In principle, a straightforward approach to obtain this information could be to undertake a controlled cooking (or brewing) test (CCT). Here, the same amount of dolo beer is prepared using a traditional stove and a Roumdé. However, such tests cannot provide more than a technical benchmark of the potential savings associated with the use of an improved stove, since the effective savings in real-world breweries might deviate from such tests for various reasons. First, breweries may use simultaneously different cooking stoves, i.e. improved and traditional ones. Second, it is unlikely that a dolotière in a CCT under observation behaves as she would behave under day-to-day conditions (known as the Hawthorne effect); for example, in reality the dolotière may do a number of activities simultaneously and, hence, cannot dedicate the same attention to her stove as a brewer in a controlled cooking test. Third, as mentioned above, the effectiveness of a stove may decline over time due to inappropriate maintenance.

Hence, in order to assess the effective savings, a large representative survey which captures the diversity of real-world cooking practices is required. A major problem that needs to be overcome is non-random-selection into the treatment group, i.e. the users of Roumdé stoves may systematically differ along a number of characteristics from non-Roumdé users. To the extent these characteristics are correlated with wood consumption, this leads to biased impact estimates, because differences in wood consumption are falsely attributed to the Roumdé. We try to redress at least the bias that stems from observable differences through the use of 'propensity score matching (PSM)'.[8] Because in our case the sample size is relatively small and the impact assessment needs to be done separately for different pairs of stoves (Roumdé stoves vs. traditional stoves and Roumdé stoves vs. improved traditional stoves) the standard matching approach is not feasible as the number of cases in the various treatment and control groups would be too small. In this case it is better to rely on a special variant of the matching approach, proposed by Hirano, Imbens and Ridder (2003) and further discussed in Hirano and Imbens (2001) in which the inverse of the propensity score is used to weight each observation in the treated group, and the inverse of one minus the propensity score (i.e. the propensity of not being in the treated group) in the control (see Hirano and Imbens, 2001; Posner and Ash, 2012). This formula is used to determine the average treatment effect, whereas Brunell and DiNardo (2004) provide an extension thereof for the treatment effect on the treated (see below), which will be used in this study. Weighting has the advantage of including all the available data. The risk is, as shown by Freedman and Berk (2008) that weighting may increase random error in the estimates, which leads to a downward bias of the estimated standard errors, even if the selection mechanism is well understood.

[8] Besides PSM, the literature proposes a number of other matching estimators (see e.g. Cameron and Trivedi, 2009).

The implementation of the procedure involved the following steps. First, we estimate a probit model of being a user of a Roumdé stove:

$$\Pr_i(T_i = 1) = \theta(\beta_0 + Z_i^{'}\beta_l + \omega_i) , \tag{1}$$

where the dependent variable is the binary outcome of a brewery i having an ICS. The underlying latent variable is the conditional probability of having an ICS. The matrix stands for a set of observable characteristics Z explaining stove ownership, such as the number of years the dolotière is already in business, her age, age squared, education and her location. The vector *ß* are the associated effects that are estimated. ω stands for the error term and Θ stands for the cumulative standard normal distribution function, i.e. the underlying probability distribution in a probit model.

Formally, the propensity score is defined as

$$e_i(Z_i) = \Pr_i(T_i = 1 | Z_i) \quad \text{with} \quad 0 < e_i(Z_i) < 1. \tag{2}$$

To attain the average treatment effect on the treated, weights can be computed from these propensity scores as outlined in Brunell and DiNardo (2004) for both treatment and control observations, denominated $\mu^{Ti = 1}$ and μ^{C} respectively:

$$\mu_i^{T = 1} = 1 \text{ and } \mu^C = \frac{Pr(T=1 | Z \quad)}{1 - Pr(T=1 | Z \quad)} \times \frac{p^C}{p^T} , \tag{3}$$

where p^T to the fraction of treatment observations and p^C to the fraction of control observations. Table A.2 (Appendix) shows the differences in the household characteristics used to estimate the probit model above before and after reweighting. Two sets of weights are used. One does exclude the other include the quantity of dolo produced. This is done, since on the one hand the quantity of dolo produced is an important correlate of adoption, on the other hand it canot be excluded that the quantity of dolo produced is altered following the adoption of a Roumdé. Hence, results are shown using both sets of weights. It can be seen that the reweighing procedure leads to an almost perfect balance; none of the differences between the group of owners and non-owners is statistically significant anymore. The impact evaluation is then based on the following regression model:

$$\ln \tilde{Y}_i = \beta_0 + \beta_1 \widetilde{ITS}_i + \beta_2 \widetilde{IS}_i + \beta_3 \tilde{X}_i + \beta_4 \tilde{Z}_i + u_i, \tag{4}$$

where $\ln \tilde{Y}_i$ stands for the outcome of interest: expenditure for firewood per brewing. The tilde indicates that all observations are reweighed with the propensity score-based weights. $\widetilde{ITS}_i$ and $\widetilde{IS}_i$ are indicator variables taking the value one if a given brewery uses an improved traditional or a Roumdé stove respectively or alternatively are shares measuring the share of brewing days that fall on improved traditional and improved stoves respectively. Hence, β_1 and β_2 are the main coefficients of interest, the saving rates associated with these two types of stoves. The saving rates are always in relation to traditional stoves. $\tilde{X}_i$ stands for a vector of characteristics relative to the brewery and the observed brewing such as the condition of the used stoves, the number of cauldrons, the quantity of dolo produced per liter, the quantities of malt and water used and the mode of wood provision. As above, $\tilde{Z}_i$ stands for a vector of characteristics of the dolotière. The term u_i stands for the error term.

Yet, since with a matching estimator a bias due to unobserved heterogeneity can never be ruled out, even if both groups are balanced across a large number of observable characteristics, we also test the robustness of our findings with a difference-in-difference estimator, i.e. we compare the changes in wood consumption over time for those that adopted between both surveys a Roumdé and those who did not. The few breweries that had already an improved stove in the 2010 survey are removed from the sample. The double-difference estimator can, in contrast to the matching estimator, also account for unobservable variables as long as they are constant over time, such as for instance astuteness. The diff-in-diff estimator can be calculated non-parametrically or in a parametric regression framework thus allowing controlling for observed time-varying characteristics that could still lead to a bias if omitted. Hence, the regression can be specified as follows:

$$\ln Y_{it} = \beta_0 + \beta_1 IS_{it} \times t_t^{2012} + \beta_2 t_t^{2012} + \beta_3 IS_i + \beta_4 X_{it} + \beta_4 Z_i + u_{it}, \quad (5)$$

where the variables follow the same notation than above. The subscript t indicates time. t_t^{2012} is an indicator variable taking the value one if a given observation is made in 2012. The coefficient of interest, the saving rate associated with the use of an improved stove, is given by β_1, the effect of the interaction effect of treatment and time conditional of time effects and being in the treatment group.

Since the 2010 survey does not allow distinguishing traditional from improved traditional stoves, Equation (5) does not differentiate between improved traditional stoves and traditional stoves. Moreover, given the small sample size of the panel and its short horizon with just two waves[9], individual fixed-effects cannot be added to Equation (5), i.e. only time-constant heterogeneity between users and non-users is removed. However, a limited set of observed

[9] The panel includes only 88 breweries. Given further missing information in outcomes and/or some of the explanatory variables, the diff-in-diff estimator is even only based on 66 observations.

time-constant characteristics, Z_i, can be added to the list of regressors to capture some of the remaining within-group heterogeneity.

A strong implicit assumption of the difference-in-difference estimator is that both groups would have evolved in the same way in absence of the program (parallel trend assumption). Another drawback specific to the case under study is that only a relatively small sub-sample of all dolotières has been interviewed in both years. This sub-sample may not be representative of all dolotières. However, representativeness can be tested by regressing an indicator variable 'being surveyed in both years' on a set of characteristics observed in 2010. Table A1 (Appendix) shows the result of such a regression. It can be seen that none of the included explanatory variables is significant, except size of the brewery as measured by the quantity of dolo made per brewing. The overrepresentation of larger breweries could introduce a bias if size of the brewery also has an effect on improved stove adoption and the consumption of firewood per litre made. This is why it will be important to take into account the size of breweries.

The principal outcome indicator we focus on is the quantity of fuel wood used per brewing process evaluated at its market price. The 'treatment' is coded in two different ways: either by a binary variable 'having or not having an improved dolo stove' or by a variable measuring the share of stove-days per brewing process that are provided by improved dolo stoves. If for example a brewery uses two stoves for production and one brewing takes two days over which both stoves are continuously in use then each stove provides two stove-days. If one of the two stoves is an improved stove, the share of stove-days provided by an improved stove is 50%. Using the binary variable it is possible to estimate the percentage reduction of fuel wood per brewing process if an improved dolo stove is in use. Using the share variable, it is possible to estimate more precisely the relative reduction of fuel wood consumption as the number of improved stove-days increases. The concept of stove-days is a better concept than the binary variable of an improved stove for breweries that work with different stoves simultaneously. Since, the quantity of dolo produced per brewing differs across breweries, as do the quantities of malt and water used, the quality of the stove and so on; these factors need to be included in the estimations. Eventually, this allows computing the average savings for Roumdé users per litre of dolo made.

4.2. Externalities on fuel-wood consuming households

To estimate the impact of the reduced price for fuel-wood induced by the adoption of improved stoves and the resulting fuel-wood savings, we proceed as follows. As a starting point we use the official estimates of the total amount of wood consumed by dolo breweries and private households (D). To this amount we apply the estimated saving rate conditional on alternative assumptions on the adoption rate of improved cook stoves among dolo breweries. This yields the change in wood consumption among dolo breweries (ΔD). Assuming that at least in the short term the aggregate wood supply is not reduced we calculate the price change ($\mathrm{d}p$) that is necessary that the wood saved by dolo breweries is completely absorbed by private households. The latter obviously requires an estimate of the price elasticity of demand, ε. As we do not have data that would allow estimating such elasticities in a reliable way, we simply make three alternative assumptions. The induced price change is given by:

$$\mathrm{d}p = \frac{p\Delta D}{D\varepsilon}. \quad (6)$$

Since wood is used for the preparation of food and food is a basic necessity, we believe that it is plausible to assume that the price elasticity, ε, is rather below than above one. Since, our data does also not allow computing cross-price elasticities, we ignore possible substitution effects. We simply estimate the welfare effect resulting from savings in wood expenditure, $\mathrm{d}W$, by multiplying for each household in our sample the induced price change, $\mathrm{d}p$, with the quantity of wood consumed, per household, q, i.e.:

$$\mathrm{d}W = q\mathrm{d}p. \quad (7)$$

Since we are not only interested in the total welfare effect or the average welfare effect per household, but also in whether the price change affects poorer households more, we compute hypothetical benefits across the entire expenditure distribution.

4.3. Environmental benefits

Pant et al. (2014) identify three dimensions on which firewood usage for cooking affect the environment. First, on the local level because of the incomplete combustion of wood in open fires smoke emissions contain pollutants that are harmful to people's health in the direct proximity of the fire. The diseases associated to such local air pollution are pneumonia, Chronic Obstructive Pulmonary Disease (COPD), and eye infections, but also stunted growth of children, tuberculosis, and cardiovascular diseases. According to the World Health

Organization, 4.3 million people die every year due to cooking induced smoke (WHO 2012). Medical research has examined the effects of air pollution induced by open fires on various illnesses for decades (see Armstrong and Campbell 1991; Campbell et al. 1989; Dherani et al. 2008, Kan et al. 2011; McCracken et al. 2011; Pandey 1984a; Pandey 1984b, and Pandey et al., 1989).

Second, on the regional level the consumption of firewood contributes to deforestation and forest degradation if fuelwood demand outpaces supply by forests. While there has been a long discussion about the extent to which firewood collection in facts leads to deforestation (see Bensch and Peters (2013) for an overview), there is compelling evidence that at least charcoal contributes substantially to deforestation. The reason is that charcoal cannot be produced out of the dead wood and small branches that are mostly collected by households for cooking purposes. Charcoal production requires larger trunks that have to be cut.

The third environmental implication of firewood usage is the emission of climate relevant substances. The emission of CO_2 that is induced by the combustion of wood is just as high as the amount of CO_2 that has been sequestered by the tree in the growing process. If only as much wood is extracted from forests as is produced by the natural growing process, the combustion of woodfuels is CO_2 neutral. Therefore, woodfuel usage only contributes to the net increase in atmospheric CO_2 to the extent that the wood is extracted in a non-sustainable manner leading to a loss of carbon sinks via deforestation or forest degradation[10]. This obviously depends on factors like biomass production and population density and is hence due to geographical variation, but for many regions it can be expected that fuelwoods are not extracted sustainably and thus firewood usage contributes to net emissions of CO2 (World Bank 2011, Martin et al. 2011, Johnson et al. 2009). In addition to CO2, the combustion of biomass based fuels is the dominant source of black carbon emissions (Baron et al. 2009). Black carbon, if gathered in high concentrations in the atmosphere, absorbs sunlight and in this way contributes substantially to short-term warming processes.[11] Shindell et al. (2012) identify the reduction of firewood consumption for cooking purposes as a promising quick win against short-term climate change processes, because unlike classical climate gases such as CO2 or methane the short-lived nature of black carbon suggests that strong immediate

[10] IPCC (2013) estimates that net land-use change, mainly deforestation, is responsible for about 10% of the total anthropogenic CO2 emissions.

[11] While the IPCC estimated the warming effect of black carbon for the first time in its 2007 report, the estimate in the current report has been revised upwards and is now twice as large as in 2007. In spite of a still high level of uncertainty, black carbon seems to be the second largest man-made contributor to global warming (after CO2), implying that its influence on climate would have been greatly underestimated so far.

action will generate immediate reduction of warming processes (see also Ramanathan (2007) and Wallack and Ramanathan (2009)).

While it is obviously beyond the scope of this study to quantify the effects of the reduction in firewood consumption on local air pollution, forests and black carbon emissions, in Section 5.4 we will present a conservative calculation of reduction in CO_2-emissions based on the methodology that is applied for the clean development mechanism (CDM), developed by the United Nations Framework Convention on Climate Change (UNFCCC).[12]

5. Results

5.1 The adoption of improved cooking stoves

In a first step a probit regression model is used to analyze the correlation between a range of socio-economic characteristics of the dolotières and characteristics of their breweries and the adoption of a Roumdé. In a second step, the role of these determinants and other factors are further scrutinized using the insights from the field visits, in-depth interviews and focus group discussions.

Theoretically, one would expect that adoption depends on at least four sets of variables: First, it should depend on the degree of energy inefficiency in the before-situation, i.e. breweries that have a high consumption of firewood per litre of produced dolo should gain most from the adoption of an improved stove. Second, adoption is also the more beneficial the higher the price of firewood. Third, adoption should depend on access to information, the intensity of marketing campaigns, i.e. dolotières need to be aware that improved stoves exist and what their savings potential is. Access to information should in turn be related to education, age, location and the interaction with other Dolotières. Fourth, it should depend on the dolotière's ability-to-pay and her access to credit.

Based on these considerations, the following explanatory variables are included in the quantitative analysis; a subset of them has also been used to implement the matching procedure: the age and age squared of the dolotière, her education, the number of years she is in business, the quantity of dolo she produces per brewing process as well as binary variables indicating whether the brewery is in Ouagadougou or in Bobo-Dioulasso and whether it is located in the urban area or outside the town in a rural community. The latter is particularly important, as in the rural communities of Bobo-Dioulasso no direct marketing has taken place

[12] See AMS-II.G „Energy efficiency measures in thermal applications of non-renewable biomass“, Version 6, United Nations Framework Convention on Climate Change.

and masons have not been trained specifically. The survey does not contain good proxies for wealth or even access to credit, as their measurement is typically very time-consuming in interviews. Dolotières are furthermore said to be relatively suspicious, what our in depth-interviews confirmed, hence questions seeking for information on wealth would have decreased their cooperativeness to accurately conduct the interview. We therefore abandoned wealth related questions in order not to jeopardize the compliance rate in our survey. However, from other studies that investigate the investment behaviour of informal firms in Ouagadougou and other West-African agglomerations, it is known that access to capital is generally an important constraint (Grimm et al., 2011). This is further discussed in conjunction with the insights from the qualitative analysis. The results of the probit model are shown in Table 5. Given that the quantity of dolo produced per brewing may change with the adoption of an improved stove, and hence the quantity produced has to be considered as endogenous, two sets of regressions are presented one with the quantity of dolo made on the right-hand-side and one without.

[please insert Table 5]

The marginal effects shown in Column (1) of Table 5, suggest that the probability of adoption is higher by 20% if the dolotière has at least completed primary education. The number of years in business has also a significant effect. Each additional year in business increases the probability of adoption by about 7%. However, the squared term is negative suggesting that this effect decreases with age. Adoption in the Ouagadougou region is much higher than in the Bobo-Dioulasso region, however this advantage mainly relates to the rural area of Ouagadougou. The reason for this has been given above. If the quantity of dolo is added to the list of regressors, the results suggest that for every percentage increase in the quantity of dolo produced, the probability of adoption increases by 0.2%. The age of the dolotière does not have a significant effect on adoption. The ethnic affiliation does have a weakly significant effect, but given the dominance of Mossi in Ouagadougou and Bobo in Bobo-Dioulasso it is difficult to disentangle this effect from the location effect.

The used questionnaire also included a module asking the dolotières without a Roumdé whether they know the Roumdé and if so, where they have heard about it. 60% of the non-users reported that they know the Roumdé. Most of them, about 79%, have heard about it from neighbors and other dolotières. Another 10% know the Roumdé from FAFASO marketing campaigns and 6% have heard about them from their masons.

Through in-depth interviews and focus group discussions, the determinants of uptake have been further explored. In general dolotières did not doubt the higher efficiency of a Roumdé, although they often mentioned that it requires a lot of effort to train staff in a way that less wood than with a traditional stove is consumed. Moreover, dolotières frequently mentioned that maintenance costs are a problem and that the investment costs of adoption are for many simply too high. Maintenance is a problem, because the way a Roumdé is conceived makes changing the cauldrons more difficult than with a traditional stove. Whereas with a traditional stove, a cauldron can simply be removed, with a Roumdé the change requires to break the mantle of the stove. This is, obviously, much more cumbersome, time-consuming and expensive. Typically, the change of cauldrons needs to be done by a mason and costs about CFA F 1,000 to 2,000[13] (although some dolotières were trained by FAFASO to enable them to make the change themselves). Given the intense heat, cauldrons made of clay have a relatively short life-span and need to be changed regularly; hence, many Dolotières believe if they switch to a Roumdé, gains from reduced firewood consumption are more than off-set by the higher costs for maintenance. Switching to aluminum cauldrons would solve the problem of maintenance somehow, as they have a longer life-span (a couple of years),[14] but it adds substantially to the investment that needs to be made up front. Depending on the size an aluminium cauldron costs between CFA F 20,000/30,000 (small) and CFA F 50,000/60,000 (large).

Increased maintenance costs are also related to the brittleness of the door of improved stoves. Since dolotières use relatively large trunks of wood, the doors often break; as they would either require to use smaller pieces of wood or at least to fill the stove with much more care. Repairing the doors is expensive in terms of time and money. Whereas a traditional stove can be maintained by the dolotières themselves, Roumdé stoves usually require a trained mason. Leaving the door broken in turn or at least not repairing it in a professional manner substantially reduces the efficiency of the stove. A Roumdé stove is also sensitive to rainfall. Many dolotières said that after the rainy season, the mantle is heavily damaged and frequently needs a professional repair. Traditional stoves might also be damaged by the wetness, but they are easier to repair and hence do not necessarily require professional help.

Moreover, it was also mentioned by many respondents that traditional stoves typically have five to six cauldrons, whereas Roumdés have only four. Hence, a Roumdé offers less brewing capacity but needs more or less the same space. A final issue which can further

[13] Cost estimate of changing the cauldrons obtained from FAFASO.
[14] It is difficult to provide an exact number here, as it depends a lot on how and how often they are used.

explain lower take-up rates around Bobo-Dioulasso (besides lower program activity) is that 8% of all breweries still report to collect their own firewood (compared to 2% in and around Ouagadougou). As a consequence, the efficiency of their stove in terms of wood consumption is less of an issue and, hence, the incentive to buy a Roumdé might be somewhat lower depending on how they perceive the time cost implied by the firewood collection.

5.2 Wood savings and rate of return

As explained above, we produce two alternative estimates: First, one based on the difference in firewood consumption between Roumdé users and non-users in 2012, where all breweries without a Roumdé are weighted according to their empirical propensity to adopt a Roumdé; second, the difference-in-differences estimate of wood consumption comparing those breweries that adopted an ICS between 2010 and 2012 and those that did not.

The key results from the econometric assessment are shown in Table 6 and in full detail in Table A.3 (Appendix). The results suggest that breweries that use at least one Roumdé (they may still use traditional stoves in addition in case they use more than one stove) spend about 18% less on firewood per brewing process than breweries that use a traditional or improved traditional stoves (but no Roumdé stove). These estimates control for the quality of the stove, for the quantity of dolo per brewing, the quantity of malt used, the quantity of water used, the number of cauldrons used, the source of the firewood purchase, the age and age squared of the dolotière, her education, her ethnicity, the time she is already in business and indicator variables for Ouagadougou, urban areas, and the corresponding interaction effect. The difference-in-difference estimator is similar in magnitude, but less precisely estimated, mainly due to the very small sample size. Because, the 2010 survey does not allow distinguishing traditional and improved traditional stoves, both categories are lumped together in the reference category. Hence what is estimated are savings relative to a mix of both types of stoves. These savings should be somewhat lower than those that one would obtain if measured in comparison to traditional stoves only.

[please insert Table 6]

Since a non-negligible share of breweries use the Roumdé and traditional stoves simultaneously, these estimates provide for an accurate assessment of how much more firewood is consumed in non-Roumdé using breweries. However, it does not provide for an estimation of how much firewood could be saved if all brewing processes were prepared on a

Roumdé stove. For this purpose, the share of stove-days that fall on a Roumdé stove is used as treatment variable. This is only possible with the 2012 data set. Moreover, the reference category is now also split into days that fall on a traditional stove and days that fall on an improved traditional stove. The corresponding results are shown in the lower part of Table 6. The estimated coefficient ranges between 0.36 and 0.38 depending on which version of the propensity score weights is used. This implies that a brewery that would switch from no Roumdé stove to only Roumdé stoves, realizes savings in firewood per brewing by about 36% to 38%. This saving rate is by roughly 40% smaller than what could theoretically be achieved if all brewing processes were done on a Roumdé (0.37/0.60). Remarkably, improved traditional stoves are at least associated with a saving rate of about 20%. Yet, the estimate is not very precise (p=16.7 to p=23.6).

Taken together the results show that the estimates are quite robust to the exact specification and weights chosen. However, a few potential sources of bias need to be discussed. First, the estimate might be downward biased, as the value of wood consumption might be reported with error. Second, the estimate might be upward biased, if uptake is correlated with unobservables that are associated with less wood consumption, such as astuteness. The bias could also be in the opposite direction, if Roumdé stoves are adopted by breweries that have unobservable characteristics that are associated with lower efficiency. However, the similarity of the saving rates identified through the matching estimator on the one hand and the difference-in-difference estimator on the other hand, suggests that the bias that stems from unobserved heterogeneity is rather negligible. Finally, there could be a problem of reverse causality: breweries with a lower consumption of firewood per litre of dolo produced are in a better position than less efficient breweries to invest in an improved stove, leading again to an overestimated saving rate. The latter is particularly relevant if credit markets fail, which in the case of dolo breweries might be often the case. In sum, given the similarity of results in the difference-in-differences and the cross-sectional estimation and since potentially remaining biases work in opposite directions, there are good reasons to believe that the above estimate is sufficiently close to the true saving rate. This is also confirmed by the fact, that the gap between the saving rate actually achieved and the potentially possible saving rate is in line with the found gap for household cooking stoves. Bensch et al. (2014) find that users of Roumdé cooking stoves realize firewood savings relative to traditional three-stones of roughly 24%, whereas the potential saving, as indicated through controlled cooking tests, stands at 40%.

A look at the included control variables (see Appendix, Table A.3) reveals some further interesting insights. First and not surprisingly, the production parameters such as the quantity of malt and water used and the number of cauldrons employed matter a lot for firewood consumption. Second, whether the wood was bought from a small retailer or a sort of "wholesale dealer" has only little effect. Third, the dolotière's education level has also no effect. Fourth, the location in Ouagadougou or Bobo-Dioulasso matters, as this does not only capture differences in the price of firewood, but also differences in the way dolo is produced.

Table 7 below converts the estimated saving rate into savings per litre of dolo produced, both in monetary terms and in terms of kg of firewood. The reported mean value of firewood consumption per litre of dolo (i.e. dividing total wood expenditures by the size of the brewing) is about CFA F 24.50, 36% of that correspond to CFA F 8.82. Using an average price of firewood of CFA F 50 per kg, allows calculating the quantity of saved firewood per litre of dolo of 0.176 kg. The total savings per brewing amount to 42.3 kg of wood or CFA F 2,117. Table 6 also provides an alternative calculation where instead of traditional stoves, improved traditional stoves are used as a reference category. Assuming two brewing processes per week, these estimates suggest that the investment in a Roumdé is amortised after 6.5 weeks if a simple traditional stove is used as reference and after 14.7 weeks if an improved traditional stove is used as reference. Given that the estimated life-span of the Roumdé is much longer, buying a Roumdé seems to be a reasonable investment as long as wood has to be bought and cannot just be collected, which seems to apply for almost all dolotières we interviewed since more than 90% in our sample reported to buy their firewood. If maintenance costs are taken into account, the amortization periods extend to 7.5 and 21.2 weeks.

[please insert Table 7]

Three factors seem particularly important for the realized savings with a Roumdé stove. First, in a typical brewery several other persons work next to the dolotières.. Even if the dolotière has some sense of how to use the improved cook stove efficiently, the other staff members do not necessarily know. Second, even if staff knows how to use a Roumdé in principle, they may not necessarily follow these rules, but rather stick to the procedures they have always applied. As explained above brewing dolo is not just a productive activity; it is an artisanry that follows first of all a tradition where the adoption of new technologies is quite uncommon. For instance, not a single brewery has been found that brews with LPG, although that would be even more energy efficient, as the temperature could be regulated over the two days in any time according to need. Third, the field visits showed that many of the improved stoves are in a very bad condition (in fact more than what the distribution of reported quality in the survey suggests). In particular the door and the inner of the combustion chamber were often damaged, due to the common practice of forcing huge trunks through the small door. These damages obviously reduce the efficiency of Roumdés quite significantly. The latter would imply, if in the estimations above we could better account for the quality of the used stoves, the estimated saving rate should be closer to the potentially possible 60%.

5.3 Household welfare effects

In this section, we assess indirect effects of the energy efficiency intervention in the dolotières sector on domestic firewood users. The increase in energy efficiency among breweries creates an excess supply of firewood, which needs to be absorbed by the demand side in order to re-establish equilibrium. Additional demand can only be created as the price decreases. By how much it must decrease to absorb the excess supply depends on the households' price elasticity of demand. The Ministry of Environment assumes that Dolo breweries in Ouagadougou account for about half of the entire wood consumed in Ouagadougou. Hence, to compute the corresponding amount of wood we use the information on wood consumption in our household data. We upscale this information using the estimated population size for Ouagadougou and our survey estimate of the average household size. This gives us the entire quantity of wood consumed by households, and given the 50% assumption, also that consumed by the dolotières. To this quantity, we then apply the monetary savings induced by the decrease of firewood consumption conditional on alternative adoption rates of improved stoves among dolo breweries. We use the actually observed Roumdé adoption rate in Ouagadougou of 44% as well as two hypothetical rates: 75% and 100%. The saving rate is, as estimated above, set at 16%. To compute the wood price that ensures full absorption of the excess supply through private woodfuel consuming households we alternatively assume a price elasticity of demand of -0.5, -1 and -1.5. An elasticity of -0.5 for instance, means that households increase their demand by 0.5% if the price decreases by 1% and so on. Since, woodfuels are a basic necessity and there are no close substitutes for poor households, we believe that a price elasticity between -0.5 and -1.0 is most plausible.

Table 8 shows the absolute and relative reduction in the price of firewood for the in total nine combinations of adoption rates and price elasticities. The observed average market price for one kg of wood is CFA F 50. Using the above estimated adoption rate among Dolo breweries of 44% and hence a sudden excess supply of wood by 2,204 tons per month leads to a decline of the price of wood by 14% if the price elasticity is low. For a high price elasticity the absorption of the excess supply would only induce a price increase of 5%. If all Dolo breweries adopted improved stoves the price decline could be as high as 11% to 32%. Again, these computations ignore that under these circumstances the supply of wood would probably go down a bit. Such price reductions could of course also lead to second-round demand effects within the group of Dolo breweries.

[please insert Table 8]

To illustrate the distributional effect of the reduced price of woodfuels we draw "benefit incidence curves", i.e. we show the relative reduction in household expenditures that is due to the reduced price. These curves are presented in Figure 2, they take into account the budget share spent on wood for each single household. Obviously, households that spend a relatively large share of their budget on woodfuels save relatively more than households that consume only little. To keep the analysis simple we apply the same saving rates for fire wood and charcoal. Figure 2a shows the savings along the household expenditure distribution for the actual adoption rate of 44%. Households in the lowest quintiles save up to 2.5% of their total expenditures if the price elasticity is low. If it is high it is rather 1%. Savings decline with increasing expenditures as households spend lower shares of their budget on wood, partly because cooking energy increase under-proportionally with total expenditures and partly because richer households use gas or other non-wood fuels for cooking. Overall the distribution of improved stove among dolo breweries has via the market for wood a clearly pro-poor effect. If all dolo breweries would adopt an improved stove poor households could save up to 6% in their household expenditures. Obviously, since warm meals are a normal good, households may spend part of their savings again on wood to consume more warm meals.

[please insert Figure 2]

5.4 Environmental benefits

The UNFCCC methodology to calculate the net CO2 savings induced by energy efficiency measures in thermal applications relies on three decisive figures: the quantity of wood saved by the intervention, the share of this savings that is non-renewable (burning renewable wood is obviously CO2-neutral), and the amount of CO2 that is emitted when burning wood. These three factors are determined in the following guided by the UNFCCC methodology.

In order to derive the quantity of wood that is saved by using the improved cooking device, UNFCCC requires taking into account an adequate baseline scenario and real-world usage behaviour. Three approaches are enumerated, the so-called controlled cooking tests (CCT) and the water boiling tests (WBT) are laboratory tests, while the third option, the kitchen performance tests (KPT), is a field test that involves intense monitoring. It can be expected that such controlled laboratory tests or intensively monitored field tests yield higher savings rates than what can be effectively observed in the field. Therefore, we use the survey data that we analysed in the previous sections. The total wood savings we obtained for the two cities – around 26,500 tons per year – thus constitute a conservative estimation within the UNFCCC methodology.

Second, the *fraction of non-renewable biomass* (fNRB), i.e. the amount of wood that can be considered as non-renewable needs to be determined. Here, the UNFCCC methodology allows for using both project specific fNRB that are specifically determined for the forests from which the wood is extracted in the project area or, instead, using conservative country specific default values for the fNRB. The default fNRB for Burkina Faso is 90%. In other words, it is expected that only 10% of the wood extracted in the country is replaced by the natural growing process. In line with this, we assume that 90% of the firewood used in the Dolo breweries in our sample is extracted in a non-renewable way and thus, the net wood savings due to the improved brewing stoves amounts to 23,850 tons per year.

Third, the amount of CO2 that is emitted when the wood is burned needs to be determined. Since the carbon content of wood varies with the type of wood, the UNFCCC methodology uses a proxy and assumes that woodfuel users would gradually switch to fossil fuels for cooking; kerosene, liquefied petroleum gas (LPG), or hard coal. UNFCCC then approximates the achieved reduction in CO2 emissions by transferring the calorific value of the economized wood into this fossil fuel mix and takes the corresponding amount of CO2 per calorific unit. The UNFCCC default for wood fuel is 0.015 TJ/tonne. Hence, the calorific value of the saved wood equals 357.75 TJ.

Since kerosene and hard coal are not used in Burkina Faso for cooking or brewing, we use the CO2 content of LPG as the emission factor, which is also a more conservative estimation given the higher CO2 intensity of kerosene and hard coal. The emission factor for LPG is 63.0 t CO2/TJ. Therefore, 22,538 tons of CO2 are saved. Burkina Faso as a whole emitted

1,683,000 tons of CO2 in 2010[15], so the achieved savings correspond to 1.3% of the emissions of the country.

6. Conclusion

In this paper we first evaluated the direct effects of an improved brewing stove program on firewood savings in local beer breweries in urban Burkina Faso and, then assessed the indirect effects of these savings on the price of firewood and hence on residential users' welfare in the affected cities. Furthermore, we approximated the intervention's effect on CO_2-emissions that is achieved through a reduced deforestation and thus of carbon sinks. Since according to the Burkinabè Ministry of the Environment the breweries absorb around half of the firewood consumption in urban Burkina Faso, considerable second-round effects on the welfare of firewood users and the environment can be expected to the extent the intervention proofs to yield first-round effects on the firewood consumption of the breweries. We used two original data sets we collected among the dolotières, and among urban households. The energy efficiency intervention in fact leads to a reduction in firewood consumption of around 16 %. For the second-round effects we use the household data set, derive firewood demand and, based on alternative price elasticities simulate the price decrease to be expected following the sudden reduction in firewood consumption of the breweries. We find a reduction in the price of firewood of the order of 5 % to 14 %, depending on the price elasticity of wood demand. As for the environmental effect, we find that around 1.3% of the overall Burkinabè CO_2-emissions are avoided due to the intervention.

The intervention therefore not only qualifies as a classical green growth policy, but also as pro-poor policy. It clearly eases adverse effects of a market failure (because social costs of firewood consumption are not fully internalized) and hence implies a Pareto-efficient improvement to the economy. In addition, the induced changes lead to a welfare increase for the poorest strata. Dercon (2014) rightly pointed out that many green growth policies require post-intervention redistribution, because in spite of a Pareto-efficient improvement the poorest strata are frequently adversely affected by such interventions. This is not the case here.[16] Two major particularities of this intervention stand out as compared to many green growth and

[15] Source: World Development Indicators, http://wdi.worldbank.org/table/3.9 (accessed on October 24, 2014). Note that no data is available on non-CO2 climate relevant emissions, so the share will be considerably lower in terms of CO2-equivalents. In developing countries, methane and nitrous oxide emissions constitute the larger share of Kyoto relevant climate gases.

[16] The group of wood sellers might suffer from a decrease in sales, but obvsiouly their number is comparatively small.

energy efficiency interventions as described in Dercon (2014): First, the targeted fuel - firewood - unlike fossil fuels is traded on regional markets and not on the world market. As a consequence, price effects materialize, which would not be the case if fossil fuel consumption is targeted. Even if substantial decreases in fossil fuel consumption are achieved, a country like Burkina Faso can hardly be expected to affect fossil fuel prices on world markets. Second, the targeted fuel is used by the vast majority of poor households in Burkina Faso on a daily basis and, hence, they benefit from the second-round effects on firewood markets. In particular, urban areas firewood is almost always bought (and not collected as in rural areas) and the related expenditures constitute a considerable burden. Energy efficiency measures that target fossil fuels or electricity consumption would hardly benefit the poorest, since these fuels are barely used by the deprived strata.

Also beyond Burkina Faso, in particular the poorest of the poor living in cities spend substantial shares of their expenditures on woodfuels. Therefore, our findings suggest that green growth policies focussing on woodfuel sectors in developing countries offer a double dividend by removing market failures with harmful consequences for both the local, regional and global environment and alleviating poverty among the poorest of the poor at the same time.

Appendix

Determinants of drop-outs

[please insert Table A.1]

Test of balancing property of matching procedure

[please insert Table A.2]

Details of regression analysis

[please insert Table A.3]

References

Armstrong, J. R. and H. Campbell (1991), Indoor Air Pollution Exposure and Lower Respiratory Infections in Young Gambian Children. *International Journal of Epidemiology*, 20: 424–9.

Arnold, J.E.M. (2006), Woodfuels, livelihoods, and policy interventions: Changing Perspectives. *World Development*, 34 (3): 596-611.

Bandiera, O. and I. Rasul (2006), Social networks and technology adoption in northern Mozambique. *Economic Journal*, 116 (514): 869–902.

Baron, R.E., W.D. Montgomery and S.D. Tuladhar (2009), An Analysis of Black Carbon Mitigation as a Response to Climate Change. Copenhagen Consensus on Climate.

Bensch, G. and J. Peters (2014), The Intensive Margin of Technology Adoption - Experimental Evidence on Improved Cooking Stoves in Rural Senegal. Ruhr Economic Papers #494. RWI, Essen.

Bensch, G., M. Grimm and J. Peters (2014), Why do households forego high returns from technology adoption: Evidence from improved cook stoves in Burkina Faso. Ruhr Economic Papers #498. RWI, Essen

Blackman, A. and G.J. Bannister (1998), Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Mexican Brickmakers. *Journal of Environmental Economics and Management*, 35: 1-21.

Bond, T. C., Doherty, S. J., Fahey, D.W., Forster, P. M., Berntsen, T., DeAngelo, B. J., Flanner, M. G., Ghan, S., K¨archer, B., Koch, D., Kinne, S., Kondo, Y., Quinn, P. K., Sarofim, M. C., Schultz, M. G., Schulz, M., Venkataraman, C., Zhang, H., Zhang, S., Bellouin, N., Guttikunda, S. K., Hopke, P.K., Jacobson, M. Z., Kaiser, J. W., Klimont, Z., Lohmann, U., Schwarz, J. P., Shindell, D., Storelvmo, T., Warren, S. G., and Zender, C. S. (2013), Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of Geophysical Research – Atmospheres*, 118: 5380–5552.

Borenstein, S. (2013), A Microeconomic Framework for Evaluating Energy Efficiency Rebound And Some Implications NBER Working Paper No. 19044, NBER.

Brunell, T. L. and J. DiNardo (2004), A Propensity Score Reweighting Approach to Estimating the Partisan Effects of Full Turnout in American Presidential Elections. *Political Analysis* 12 (1): 28-45.

Cameron, A.C. and P.K. Trivedi (2009), Microeconometrics using STATA, , STATA Press: College Station.

Campbell, H., J. R. Armstrong and P. Byass (1989), Indoor Air Pollution in Developing Countries and Acute Respiratory Infection in Children. *Lancet*, 1: 1012.

Conley, T.G. and C.R. Udry (2010), Learning about a New Technology: Pineapple in Ghana. *American Economic Review*, 100 (1): 35-69.

Deaton, A. (1997), *The Analysis of Household Surveys: A Microeconomic Approach to Development Policy*. The John Hopkins University Press, World Bank.

Deaton, A. (2003), Prices and poverty in India 1987–2000. *Economic and Political Weekly*, 25: 362– 368.

Dercon, S. (2014), Is green growth good for the poor? *World Bank Research Observer*, 29 (2): 163-185.

Dherani, M., Pope, D., Mascarenhas, M., Smith, K.R., & Weber, M. &. (2008). Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under 5 years: a systematic review and meta-analysis. *Bulletin of the World Health Organization*, 86 (5): 390-398.

Diaz E., T. Smith-Sivertsen, D. Pope, R.T. Lie, A. Diaz, J. McCracken, B. Arana, K.R. Smith and N. Bruce (2007), Eye discomfort, headache and back pain among Mayan Guatemalan women taking part in a randomized stove intervention trial. *Journal of Epidemiology and Community Health*, 61 (1): 74-79.

Duflo, E., M. Kremer, and J. Robinson (2011). Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya. *American Economic Review*, 101 (6): 2350-90.

Foster, A. and M. Rosenzweig (1995). Learning by Doing and Learning form Others: Human Capital and Technical Change in Agriculture. *Journal of Political Economy,* 104: 1176-1209.

Freedman D. and R.A. Berk (2008), Weighting Regressions by Propensity Scores, *Evaluation Review*, 32: 392 - 409.

Friedman, J. and J. Levinsohn (2002), The distributional impacts of Indonesia's financial crisis on household welfare: A “rapid response” methodology. *World Bank Economic Review*, 16*(*3*)*, 397–423.

Grimm, M., J. Krüger and J. Lay (2011), Barriers to entry and returns to capital in informal activities: Evidence from Sub-Saharan Africa. *Review of Income and Wealth,* 57: S27-S53.

Günther I. and M. Grimm (2007), Measuring pro-poor growth when relative prices shift, *Journal of Development Economics*, 82 (1): 245-256.

Hanna R., E. Duflo and M. Greenstone (2012), Up in Smoke: the Influence of Household Behavior on the Long-run Impact of Improved Cooking Stoves. Massachusetts Institute of Technology Department of Economics Working Paper 12-10. Boston, MA.

Hicks, J.R. (1939), *Value and capital: An inquiry into some fundamental principles of economic theory* Oxford: Clarendon Press.

Hirano, K. and G. W. Imbens. 2001. “Estimation of Causal Effects Using Propensity Score Weighting: An Application to Data on Right Heart Catheterization.” *Health Services and Outcomes Research Methodology* 2 (3-4): 259-78.

Hirano, K., G. W. Imbens, and G. Ridder. 2003. “Efficient Estimation of Average Treatment Effects Using the Estimated Propensity Score.” *Econometrica* 71 (4): 1161-89.

IPCC (Intergovernmental Panel on Climate Change). (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York: Cambridge University Press.

Johnson M., Edwards R., Ghilardi A., Berrueta V., Gillen D., Frenk C.A. and Masera O. (2009), Quantification of carbon savings from improved biomass cookstove projects. *Environmental Science & Technology*. 43: 2456–2462.

Kan, X., Chiang, C.Y., Enarson, D., Chen, W., et al. (2011), Indoor solid fuel use and tuberculosis in China: a matched case-control study. *BMC Public Health*, 11(1), 1-7.

Madlener, R. and B. Alcott (2009), Energy rebound and economic growth: A review of the main issues and research needs. *Energy*, 34 (3): 370–376.

Martin II., W. J., Glass, R. I., Balbus, J.M. and Collins, F.S. (2011). A major environmental cause of death, *Science,* 334 (6053): 180-81.

Masera O., R. Edwards, C.A. Arnez, V. Berrueta, M. Johnson, L.R. Bracho, H. Riojas-Rodriguez and K.R. Smith (2007), Impact of "Patsari" improved cookstoves on Indoor Air Quality in Michoacán, Mexico. *Energy for Sustainable Development*, 11 (2): 45-56.

McCracken, J., Smith, K., Stone, P., Díaz, A., Arana, B., & Schwartz, J. (2011). Intervention to Lower Household Wood Smoke Exposure in Guatemala Reduces ST-Segment Depression on Electrocardiograms. *Environmental Health Perspectives,* 119(11), 1562-1568.

Pandey, M. R. (1984a). Prevalence of Chronic Bronchitis in a Rural Community of the Hill Region of Nepal. *Thorax,* 39: 331–6.

Pandey, M. R. (1984b). Domestic Smoke Pollution and Chronic Bronchitis in a Rural Community of Hill Region of Nepal. *Thorax*, 39: 337–3399.

Pandey, M. R. et al. (1989). Indoor Air Pollution in Developing Countries and Acute Respiratory Infection in Children. *Lancet*, 1: 427–429.

Pant, KP, SK Pattanayak, and MBM Thakuri (2014), Climate change, cook stoves, and coughs and colds: Thinking global and acting local in rural Nepal. Chapter 5 in S. Barrett, KG Mäler, and ES Maskin (ed). *Environment and Development Economics: Essays in Honor of Sir Partha Dasgupta*. Oxford University Press. Pp 145 – 168.

Posner M.A. and A.S. Ash (2012), Comparing Weighting Methods in Propensity Score Analysis. Mimeo, Villanova University.

Prais, S.J . (1959), Whose cost of living? *Review of Economic Studies*, 26: 126– 134.

Ramanathan, V. (2007). Role of Black Carbon in Global and Regional Climate Changes," testimonial to the House Committee on Oversight and Government Reform, Chair: The Honorable Henry A. Waxman. September 2007.

Ribot J.C. (1999), A history of fear: imagining deforestation in the West African dryland forests. *Global Ecology and Biogeography*, 8 (3-4): 291–300.

Sanogo O., T. Traoré/Zizien, C. Roamba and D. Zerbo (2011), Etude de la Production de dolo dans la région Centre et dans la zone de Bobo-Dioulasso, IRSAT, Ouagadougou, Burkina Faso.

Shindell, D., Kuylenstierna, J. C. I., Vignati, E., van Dingenen, R., Amann, M., Klimont, Z., Anenberg, S. C., Muller, N., Janssens-Maenhout, G., Raes, F., Schwartz, J., Faluvegi, G., Pozzoli, L, Kupiainen, K., H¨oglund-Isaksson, L., Emberson, L., Streets, D., Ramanathan, V., Hicks, K., Kim Oanh, N. T., Milly, G., Williams, M., Demkine, V., and Fowler, D. (2012), Simultaneously mitigating near-term climate change and improving human health and food security. *Science* 335: 183–189.

Smith-Sivertsen, T., E. Diaz, D. Pope, R. T. Lie, A. Diaz, J. McCracken, P. Bakke, B. Arana, K. R. Smith, and N. Bruce. 2009. Effect of Reducing Indoor Air Pollution on Women's Respiratory Symptoms and Lung Function: The RESPIRE Randomized Trial, Guatemala. *American Journal of Epidemiology* 170 (2): 211-20.

Wallack, J. S. and V. Ramanathan (2009), The Other Climate Changers: Why Black Carbon and Ozone Also Matter. *Foreign Affairs*, 88(5): 105–13.

WHO (2012) Global Burden of Disease Study (2010), A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis. *Lancet*, 380, 2224-2260.

Wodon, Q.T., C. Tsimpo, P. Backiny-Yetna, G. Joseph, F. Adoho and H. Coulombe (2008), Potential Impact of Higher Food Prices on Poverty: Summary Estimates for a Dozen West and Central African Countries. World Bank Policy Research Working Paper Series, World Bank, Washington D.C.

World Bank (2011) Household Cookstoves, Environment, Health, and Climate Change – A New Look at an Old Problem. World Bank, Washington D.C.

Yu F. (2011), Indoor Air Pollution and Children's Health: Net Benefits from Stove and Behavioral Interventions in Rural China. *Environmental and Resource Economics*, 50 (4): 495-514.

Tables and Figures

Table 1: Number of improved dolo stoves (Roumdé) installed by location and year

Location	2010	2011	2012	Total
Ouagadougou	93	592	181	866
Bobo-Dioulasso	29	336	58	423
Sud-Ouest	280	241	143	664
Est	154	105	105	364
Total	556	1,274	487	2,317

Source: FAFASO.

Figure 1: Photographs of a Roumdé and two traditional stoves

(a) Roumdé

(b) Traditional stove (most rudimentary)

(c) Traditional stove (slightly improved)

Table 2: Sample composition (2010, 2012, panel)

	Breweries interviewed in…		
	2010	2012	Both years
Ouagadougou	156	178	72
Bobo-Dialousso	61	83	16
Total	217	261	88

Source: Own calculations, based on Brewery Surveys 2010 and 2012.

Table 3: Characteristics of respondents

	2010	2012
Age (years)	43.7	45.9
At least primary completed (=1)	0.24	0.23
Ethnic group		
Mossi (=1)	0.67	0.63
Bobo (=1)	0.25	0.27
In Dolo business (years)	14.4	16.4
Ouagadougou/Centre Region	0.72	0.68
Urban (=1)		0.30
N	217	261

Note: Urban/rural has not been coded in 2010

Source: Own calculations, based on Brewery Surveys 2010 and 2012.

Table 4: Characteristics of breweries in 2012

	Ouaga		Bobo		Bobo city only	
	mean	Sd	mean	sd	mean	sd
Number of paid employees	1.09	2.05	0.37	0.74	1.00	0.98
Number of stoves	1.79	0.92	0.48	0.50	1.50	0.58
Distribution of stoves by type						
Number of traditional stoves	0.12	0.45	0.48	0.50	0.12	0.33
Number of improved traditional stoves	0.85	0.91	0.42	0.59	0.62	0.75
Number of Roumdé stoves	0.81	1.02	0.27	0.61	0.77	0.82
Share of breweries with at least one Roumdé	0.49		0.18		0.54	0.51
Number of cauldrons	6.58	3.52	5.89	2.65	8.08	3.07
Type of cauldrons (shares of stoves)						
Aluminium	0.93	0.25	0.01	0.11	0	0
Clay	0.04	0.21	0.98	0.15	1.00	-
Age of stove	8.51	12.41	10.34	9.58	9.38	11.23
Condition of stoves (shares of stoves)						
Good	0.50	0.44	0.85	0.35	0.61	0.48
Cracks	0.36	0.45	0.11	0.30	0.31	0.43
Shaby	0.14	0.31	0.04	0.16	0.08	0.20
Number of brewings per week	1.99	0.85	1.71	1.60	1.58	0.88
Share of brewing days by type of stove						
Improved traditional stove	0.51	0.42	0.95	0.48	0.38	0.50
Roumdé stove	0.44	0.48	0.17	0.38	0.50	0.51
Share breweries using only improved Roumdé	0.38		0.17		0.50	0.51
Quantity of Dolo per brewing (in liter)	368.91	277.80	159.45	79.24	217.50	95.43
Quantity of malt per brewing (in kg)	85.37	77.72	41.26	16.77	57.24	18.55
Quantity of water per brewing (in barrel)	7.26	8.08	2.70	1.07	3.65	0.98
Expenditure for firewood per brewing*	8,956.90	9,939.61	4,149.67	2,968.83	7,375.00	2,096.72
Wood delivery (share of breweries)						
Collecting or cutting wood	0.02		0.08		0	0
Buys in small quantities	0.22		0.34		0.35	0.49
By cart	0.40		0.46		0.23	0.43
By lorry	0.03		0.01		0.38	0.20
By truck	0.32		0.12		0.38	0.50
Number of observations	178		83		26	

Note: *Not counting those who collect or cut their own fuel wood. In Bobo-Dialousso marketing campaigns and training activities of masons have been limited to the city of Bobo-Dialousso that is why we show all statistics also separately for the city of Bobo-Dialousso.
Source: Own calculations, based on Brewery Survey 2012.

Table 5: Uptake of Roumdé stoves, probit model, marginal effects

Dep. Var.: Uses a Roumdé stove	Coeff. (S.E.)	Coeff. (S.E.)
Ln quantity of Dolo per brewing (in liter)		0.199
		(0.070)***
Age dolotière	0.008	0.008
	(0.022)	(0.022)
Age dolotière (sq.)	0.000	0.000
	(0.000)	(0.000)
At least primary completed (=1)	0.200	0.170
	(0.078)**	(0.080)**
Mossi (=1)	0.214	0.227
	(0.121)*	(0.123)*
Bobo (=1)	0.272	0.304
	(0.185)	(0.183)*
In Dolo business (years)	0.030	0.024
	(0.012)**	(0.012)*
In Dolo business (years) (sq.)	-0.001	0.000
	(0.000)*	(0.000)
Ouagadougou/Centre Region	0.600	0.542
	(0.089)***	(0.103)***
Urban (=1)	0.774	0.740
	(0.104)***	(0.117)***
Ouagad. x Urban (Interaction)	-0.547	-0.552
	(0.051)***	(0.051)***
Pseudo R2	0.236	0.261
N	253	253

Notes: The coefficients show marginal effects, i.e. the change in the probability of uptake for a one unit-change in the explanatory variable (or a change from 0 to 1 for binary categorical variables). * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses.
Source: Own estimations, based on Brewery Survey in 2012.

Table 6: Impact of Roumdé usage on firewood consumption in CFA F (log)

	OLS-CS 2012 PS-weights I	OLS-CS 2012 PS-weights II	Diff-in-Diff non-param.	Diff-in-Diff parametric
Uses a traditional/improved traditional stove	Ref.	Ref.	Ref.	Ref.
Uses a Roumdé stove	-0.182	-0.187	-0.213	-0.143
	(0.064)***	(0.064)***	(0.612)	(0.340)
N	*236*	*236*	*66*	*66*
Share of brewing-stove-days with a traditional stove	Ref.	Ref.		
Share of brewing-stove-days with an improved traditional stove	-.200	-0.214		
	(0.168)	(0.154)		
Share of brewing-stove-days with a Roumdé stove	-0.358	-0.376		
	(0.163)**	(0.153)**		
N	*236*	*236*		

Notes: The results of each regression are shown in detail in Annex 4. * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses.
Source: Own estimations, based on Brewery Surveys 2010 and 2012.

Table 7: Wood savings related to Roumdé usage in terms of value and quantity

	Ref.: traditional stove	Ref.: improved traditional stove
Estimated saving rate	36%	16%
Mean firewood expenditure per litre of dolo	CFA F 24.50	CFA F 24.50
Saved firewood expenditures per litre of dolo	CFA F 8.82	CFA F 3.92
Price of firewood per kg	CFA F 50.00	CFA F 50.00
Saved firewood in kg per litre of dolo	0.176 kg	0.078 kg
Average size of a brewing (median)	240 liter	240 liter
Saved firewood per brewing in kg	42.336 kg	18.720 kg
Saved firewood per brewing in CFA F	CFA F 2,116.80	CFA F 936.00
Price of a Roumdé stove	CFA F 27,500	CFA F 27,500
Weeks until amortization, 2 brewings per week assumed	6.5	14.7
Weeks until amortization accounting for maintenance costs (CFA F 30,000 assumed annually)	7.5	21.2

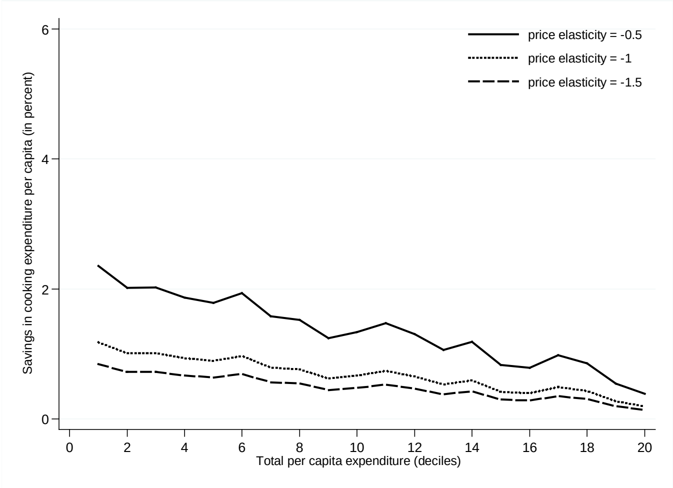
Source: Own estimations, based on Brewery Surveys 2010 and 2012.

Table 8: Price changes absolute and relative (in italics) induced by wood savings among breweries

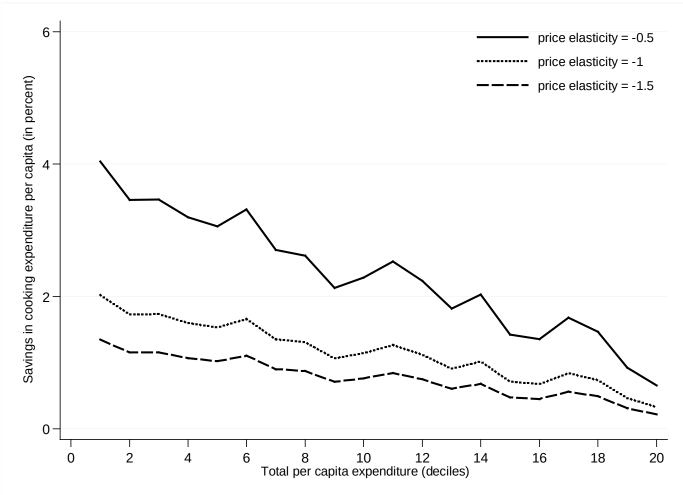
Adoption rate (*Aggregate saving rate over all breweries*)	Assumed price elasticity of demand (ε)		
	-0.5	-1	-1.5
0.44	-7.04	-3.52	-2.35
(0.07)	*-0.14*	*-0.07*	*-0.05*
0.75	-12.00	-6.00	-4.00
(0.12)	*-0.24*	*-0.12*	*-0.08*
1.00	-16.00	-8.00	-5.33
(0.16)	*-0.32*	*-0.16*	*-0.11*

Notes: The initial average price of wood is CFA F 50.
Source: Own computation.

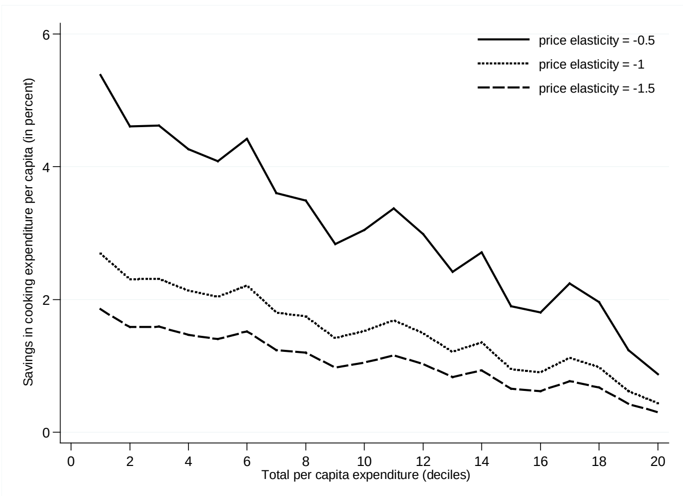
Figure 2: Simulated savings in cooking expenditure induced by price effect



(a) Actual adoption rate (44%)



(b) Hypothetical adoption rate (75%)



(c) Hypothetical adoption rate (100%)

Table A.1: Analysis of drop-outs, probit model

Dep. var.: interviewed in 2012 given that an interview took place in 2010 (=1)	Coeff. (S.E.)
Age	0.003
	(0.011)
Mossi (=1)	-0.372
	(0.410)
Bobo (=1)	-0.353
	(0.501)
In Dolo business (years)	-0.007
	(0.012)
Ouaga	0.281
	(0.451)
Has improved stove (in 2010)	0.271
	(0.267)
Ln of quantity dolo produced (in 2010)	0.539**
	(0.217)
Constant	-3.120
	(1.158)***
N	192

Notes: Due to missing information in the characteristics, 25 observations had to be excluded from this regression.
Source: Own estimations, based on Brewery Surveys 2010 and 2012.

Table A.2: Test of balancing property of matching procedure

	User of Roumdé stove	Non-user of Roumdé stove Unweighted	Non-user of Roumdé stove weighted	Pre-weighing difference
Variable set weights I				
Age dolotière	46,911	45,340	47,512	
Age dolotière (sq.)	2313,149	2168,948	2376,088	
At least primary completed (=1)	0,388	0,135	0,361	***
In Dolo business (years)	18,553	15,151	17,725	***
In Dolo business (years) (sq)	432,553	325,818	408,905	**
Ouagadougou/Centre Region	0,854	0,381	0,849	***
Urban (=1)	0,330	0,160	0,327	***
Ouagad. X Urban (Interaction)	0,194	0,116	0,187	**
Variable set weights II (those above and …)				
Ln quantity of Dolo per brewing (in liter)	5,753	5,313	5,737	***

Note: Difference: * significant at 10%, ** significant at 5%, *** significant at 1%. Values for Roumdé stove users are identical before and after weighting as a weight of 1 is assigned to these observations.
Source: Own estimations, based on Brewery Survey 2012.

Table A.3: Details of regressions shown in Table 9 (impact of Roumdé on firewood consumption)

	OLS-CS 2012 PS-weights I	OLS-CS 2012 PS-weights II	OLS-CS 2012 PS-weights I	OLS-CS 2012 PS-weights II	Diff-in-Diff param.
Type of stove used[a)]					
Traditional/traditional improved stove	Ref.	Ref.			Ref.
Roumdé stove	-0.182***	-0.185***			-0.143
	(0.064)	(0.064)			(0.340)
Type of stove used by share of brewing days					
Traditional stove			Ref.	Ref.	
Improved traditional stove			-0.199	-0.214	
			(0.168)	(0.154)	
Roumdé stove			-0.358**	-0.376**	
			(0.163)	(0.153)	
Condition of stove by share of brewing days					
Good	Ref.	Ref.	Ref.	Ref.	
Cracks	0.036	0.071	0.053	0.094	
	(0.081)	(0.073)	(0.083)	(0.075)	
Shaby	0.104	0.070	0.080	0.071	
	(0.135)	(0.106)	(0.116)	(0.102)	
Ln Number of cauldrons	0.428***	0.314***	0.434***	0.307***	
	(0.120)	(0.096)	(0.124)	(0.095)	
Ln quantity of Dolo per brewing (in liter)	0.045	0.138	0.065	0.157	0.083
	(0.126)	(0.116)	(0.123)	(0.114)	(0.274)
Ln quantity of malt per brewing (in kg)	0.491**	0.404**	0.458**	0.371**	1.112***
	(0.205)	(0.168)	(0.197)	(0.166)	(0.272)
Ln quantity of water per brewing (in barrel)	0.119	0.258*	0.118	0.268*	
	(0.172)	(0.141)	(0.165)	(0.136)	
Wood delivery (share of breweries)					
Buys in small quantities	Ref.	Ref.	Ref.	Ref.	Ref.
By cart	-0.037	-0.038	-0.045	-0.057	-0.250
	(0.084)	(0.075)	(0.083)	(0.073)	(0.160)
By lorry	-0.007	0.022	-0.029	0.007	0.268
	(0.101)	(0.095)	(0.112)	(0.104)	(0.249)
By truck	0.155*	0.102	0.157*	0.102	0.343
	(0.079)	(0.075)	(0.082)	(0.077)	(0.281)
Age dolotière	-0.059**	-0.048*	-0.064***	-0.054**	
	(0.025)	(0.025)	(0.024)	(0.025)	
Age dolotière (sq.)	0.001***	0.001**	0.001***	0.001**	
	(0.000)	(0.000)	(0.000)	(0.000)	
At least primary completed (=1)	0.129	0.005	0.122	0.002	-0.184
	(0.113)	(0.080)	(0.107)	(0.078)	(0.230)

Table continues next page.

Table A.3: Table (… *continued*)

	OLS-CS 2012 PS-weights I	OLS-CS 2012 PS-weights II	OLS-CS 2012 PS-weights I	OLS-CS 2012 PS-weights II	Diff-in-Diff param.
Ethnic group					
Mossi (=1)	-0.166	-0.233**	-0.196	-0.257**	-0.415*
	(0.131)	(0.117)	(0.121)	(0.116)	(0.221)
Bobo (=1)	0.165	0.159	0.141	0.170	-0.719**
	(0.117)	(0.110)	(0.121)	(0.112)	(0.313)
Other (=1)	Ref.	Ref.	Ref.	Ref.	Ref.
In Dolo business (years)	0.006	-0.001	0.009	-0.002	
	(0.010)	(0.011)	(0.011)	(0.011)	
In Dolo business (years) (sq)	-0.000	-0.000	-0.000	-0.000	
	(0.000)	(0.000)	(0.000)	(0.000)	
Ouagadougou/Centre Region	0.802***	0.705***	0.875***	0.799***	-0.299
	(0.133)	(0.129)	(0.165)	(0.160)	(0.322)
Urban (=1)	0.968***	0.934***	1.013***	0.993***	
	(0.095)	(0.093)	(0.126)	(0.115)	
Ouagad. x Urban (Interaction)	-0.730***	-0.730***	-0.754***	-0.772***	
	(0.127)	(0.119)	(0.142)	(0.129)	
Time effect (2012)					-0.561***
					(0.163)
Treatment group (user of Roumdé)					-0.038
					(0.275)
Intercept	5.565***	5.416***	5.842***	5.714***	-1.235
	(0.887)	(0.792)	(0.767)	(0.768)	(1.499)
R-squared	0.766	0.806	0.768	0.807	0.655
N	236	236	236	236	66

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Robust standard errors in parentheses.
Source: Own estimations, based on Brewery Surveys 2010 and 2012.