Credit and attention in the adoption of profitable energy efficient technologies in Kenya

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Abstract

What roles do credit constraints and inattention play in the under-adoption of high-return technologies? We study this question in the case of energy efficient cookstoves in Nairobi. Using a randomized field experiment with 1,000 households, we find that the technology has very high returns—we estimate an average rate of return of 300% and savings of $120 per year in fuel costs, around one month of income. In spite of this, adoption rates are inefficiently low. Using a Becker-DeGroot-Marschak mechanism, we find that average willingness-to-pay (WTP) is only $12. To investigate what drives this puzzling pattern, we cross-randomize access to credit with two interventions designed to increase attention to the costs and the benefits of adoption. Our first main finding is that credit doubles WTP and closes the energy efficiency gap. Second, credit works in part through psychological channels: around one-third of the impact of credit is caused by inattention to future costs. We find no evidence of inattention to energy savings. These findings have implications for second-best regulation of pollution externalities using subsidies versus taxes. In the presence of credit constraints, Pigovian taxation alone may no longer be the optimal policy. Factoring in private benefits and avoided environmental damages, we estimate welfare gains of $700 for every energy efficient stove adopted and used for two years. A subsidy would have a marginal value of public funds of $19 per $1 spent.

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1 Introduction

Low- and middle-income countries are expected to propel global energy demand in the next several decades, in part due to the widespread adoption of household appliances (Wolfram et al. 2012). This will exacerbate climate change, since energy accounts for 80 percent of global CO_2 emissions. Energy efficient technologies are often cited for their potential to meet sustainable development goals by slowing greenhouse gas emissions while also generating financial savings for households. The International Energy Agency (2018), for example, proposes that 44 percent of all global emissions reductions by 2040 could come from energy efficiency gains. Despite this, adoption of energy efficient technologies remains low.

We implement a randomized controlled trial (RCT) with 1,000 households in Nairobi, Kenya to study the roles of credit constraints and inattention in households' demand for an energy efficient replacement to their primary[1] energy consuming appliance—a charcoal cookstove. To quantify the determinants of adoption we cross-randomize credit and attention treatments prior to the adoption decision. We then provide respondents with varying subsidies for the stove and use the resulting random variation to estimate the causal impact of stove adoption on charcoal expenditures.

We estimate an average internal rate of return of 300 percent,[2] saving USD 120 per year. This departs from previous estimates that find low or even negative returns to energy efficiency (e.g. Fowlie et al. 2018). In spite of these high returns, willingness-to-pay (WTP) is inefficiently low. We find that a three-month loan doubles WTP and is sufficient to close the *energy e ciency gap*[3] over the period of the loan. This finding is consistent with a large literature in development showing that credit constraints limit poor households' ability to invest in welfare-improving technologies (Banerjee and Duflo 2005). We find evidence that credit operates in part through psychological mediators: inattention to future costs increases the impact of credit. However, unlikely many papers in the U.S. (e.g. Allcott and Wozny 2014), we find that agents are not inattentive to energy savings, suggesting nudges may not be an effective policy tool in this context. Finally, we demonstrate that our findings have meaningful implications for the efficacy of Pigovian taxation (Pigou 1920) relative to subsidies in regulating environmental externalities in the presence of large credit constraints.

We first document that the energy efficient cookstove we study has a high rate of return but adoption is inefficiently low. We use a Becker et al. (1964) (BDM) mechanism to si-

[1]Households were eligible if they used a traditional charcoal stove as their main source of energy for cooking. Charcoal expenditures constitute 66 percent of average household energy expenditures.

[2]While the stove generates large health benefits, for low-income households cost savings are the most salient: 14 percent of median income is spent on charcoal.

[3]Global under-adoption of energy efficient technologies, often referred to as the *'energy efficiency gap'*, has long puzzled researchers (see for example Jaffe and Stavins 1994).

multaneously elicit WTP for and induce random variation in stove adoption. This allows us to causally estimate household energy savings and quantify the gap between total savings and household WTP. We find evidence of significant under-adoption consistent with a large energy efficiency gap. Using the random price assigned in the BDM mechanism as an instrumental variable for cookstove adoption, we estimate that adoption of the stove causes households to reduce charcoal spending by 39 percent.[4] This is equivalent to USD 120 per year for the median respondent—a month's worth of income. Given the stove's market price of USD 40, this implies an internal rate of return of 23 percent per month,[5] or 300 percent per year. In spite of these large savings, control households' average WTP is only USD 12. To rationalize such low WTP with only exponential discounting, households would need discount factors of 0.88 per week.[6] This is well beyond most estimates of discount rates in the literature.[7]

We explore two possible mechanisms driving this under-adoption. First, we randomize access to credit to test for financial constraints, which are widely documented in development economics.[8] Second, we cross-randomize two interventions designed to increase attention to the costs and the benefits of adoption prior to the BDM elicitation. Energy efficient technologies are often characterized by a large up-front investment that yields relatively minor savings in any single future time period. Behavioral theory suggests that households may over-attend to these significant present costs and neglect recurring future energy savings.[9,10] Our intervention is designed to counter this tendency by inducing households to track charcoal consumption for the month prior to the elicitation, have them forecast the savings over the next year, and imagine what they could do with these savings.

Credit is a primary driver of adoption. A three-month loan[11] increases average WTP by 104 percent, from USD 12 to USD 25. Credit is sufficient to close the energy efficiency gap over the period of the loan. It appears that credit constraints prevent households from adopting technologies even when these have an expected return of 300 percent.

[4] Our empirical estimate aligns closely with engineers' ex ante predictions. Previous papers often find a gap between predicted and realized savings (Davis et al. 2018; Burlig et al. 2019; Myers 2019).

[5] M-Shwari, Kenya's largest mobile lending platform, offers loans at 7.5 percent in fees per month; however, these loans come with restrictions on loan size and duration. M-shwari is available to all M-Pesa customers.

[6] A risk-neutral household seeking to break even after two years (the stove's warranty period) requires a discount factor δ such that $12 = \sum_{t=1}^{104} \delta^t 2$, where USD 12 is average WTP and USD 2 is estimated weekly savings. Households would be indifferent between USD 10 today and USD 10,365 in one year.

[7] For example, Dasgupta (2009) uses social annual discount rates between 3-6 percent and Banerjee and Duflo (2005) use an annual discount rate of 5 percent.

[8] See Banerjee et al. (2015), Mel et al. (2008), Pitt and Khandker (1998), and Karlan et al. (2014).

[9] 60 percent of respondents purchase charcoal daily. Savings in each period are therefore likely small.

[10] See for example Bordalo et al. (2013), Gabaix and Laibson (2017), and DellaVigna (2009).

[11] The loan has an interest rate of 1.16 percent per month. This was the monthly interest rate (excluding fees) offered to M-Shwari customers during the study design period.

We find evidence that myopia contributes to the large impact of credit. In other words, the large impact of credit widely documented in development economics may not be due to relaxing credit constraints alone. Credit changes the structure of costs, from a single bulky payment up front to multiple smaller payments in the future. This may make credit more attractive for agents that are inattentive to the future, or agents that exhibit time-inconsistent behavior more broadly.[12] We find evidence that this is the case. When households in the attention control are given a loan, their WTP increases by around USD 13. But when households are encouraged to attend to their future loan payments during the forecasting exercise in the attention treatments, WTP increases by only USD 9—an economically and statistically significantly lower amount. This effect is driven by respondents whom we identify to be time-inconsistent through an independent effort task allocations exercise (Augenblick et al. 2015). The impact of credit is larger among time-inconsistent agents, but this difference is moderated for agents in the attention treatment group, suggesting that existing measures of time inconsistency may in part reflect myopia towards the future rather than preferences.

On the other hand, we do not find any evidence of inattention to energy savings: in spite of its intensity, the intervention does not affect any portion of the WTP distribution. It may be that the repeated purchase of charcoal on a daily basis already makes these expenditures salient. We also test for concentration bias (Koszegi and Szeidl 2013) as a source of inattention: an agent exhibiting concentration bias will attend less to the total cost when it is dispersed across numerous payments rather than concentrated in a single large payment.[13] We test for concentration bias in both benefits and costs, and find no evidence of either. Behavioral nudges designed to increase attention to energy savings are unlikely to meaningfully increase adoption of energy efficient technologies in this context.

Finally, we explore the implications of credit market failures for the efficiency of policies targeting poverty and addressing environmental externalities in low-income contexts. We estimate that, for the average user, the aggregate welfare benefits from two years of stove usage[14] consist of financial savings (USD 214), avoided environmental damages[15] (USD 207), and time savings (USD 231), yielding an average total welfare gain of USD 651 per stove adopted. In an efficient market, Pigovian taxes are considered first-best in addressing environmental externalities (Pigou 1920). We demonstrate that in credit constrained settings,[16]

[12] Angeletos et al. (2001) find that households with hyperbolic preferences borrow more. Time-inconsistent behavior could be driven by present biased preferences, anticipated changes to marginal utility, or general inattention or myopia towards future costs. See O'Donoghue and Rabin (1999), Dean and Sautmann (2019), DellaVigna (2009), Gabaix and Laibson (2017), and Cassidy (2019) for more detail.

[13] Field and Pande (2008) find that assignment into weekly or monthly payment structures has no impact on delinquency or default of micro-finance loans in India; however, they do not test for an impact on take-up.

[14] All welfare benefits calculations incorporate an 0.9 annual discount factor.

[15] Assuming a USD 42 social cost of carbon (EPA 2016). We present alternative SCC estimates in section 6.

[16] The first-best policy solution is to improve credit markets. A detailed understanding of how to achieve

and when demand for utilization of the energy-intensive technology is relatively inelastic,[17] a combination of a subsidy on the energy efficient technology and a tax on the dirty good that is lower than the environmental damages is more efficient than the standard Pigovian tax. This result matters because low-income country governments are increasingly implementing carbon taxes to reduce emissions of greenhouse gases. For example, South Africa, Chile, and Mexico have all enacted a carbon tax covering at least 40 percent of their national greenhouse gas emissions (World Bank 2018). These taxes are expected to increase electricity and gasoline prices, but, under large credit constraints, may not achieve the intended welfare gains. We argue that policy makers should instead consider subsidies for energy efficient technologies. Given a 1.13 marginal cost of public funds, a USD 30 subsidy would have a marginal value of public funds of USD 19 per USD 1 spent.

This paper contributes to a large literature documenting credit constraints and other barriers to technology adoption in developing countries (Duflo et al. 2008; Mel et al. 2008; Banerjee et al. 2015; Pitt and Khandker 1998; Karlan et al. 2014; Banerjee and Duflo 2014; Casaburi and Willis 2018; Blattman et al. 2014, and many others). We document that households are unable to use credit to invest in technologies even when the expected internal rate of return is 300 percent. In finding high take-up and large returns, we depart from a large literature that generally finds low adoption and limited impacts of improved cookstoves in particular (Pattanayak et al. 2019, Hanna et al. 2016, Levine et al. 2018, Mobarak et al. 2012, Burwen and Levine 2012, Beltramo and Levine 2010, Chowdhury et al. 2019).

We build on growing evidence documenting behavioral biases among individuals living in poverty. While credit constraints are widely studied, there is less evidence on whether households in low-income contexts evaluate cost-benefit trade-offs in technology adoption decisions with any substantial biases. On the one hand, because the potential savings are a significant portion of households' consumption, households may attend to these savings more carefully and make optimal trade-offs (Shah et al. 2015; Fehr et al. 2019; Goldin and Homonoff 2013). On the other hand, the cognitive stress of being poor can impair households' decision-making capabilities (Haushofer and Fehr 2014; Schilbach et al. 2016; Kremer et al. 2019), including during technology adoption or business investment decisions (Duflo et al. 2011; Kremer et al. 2013; Liu 2013). We contribute to this literature by studying behavioral biases in a real life, high-stakes technology adoption decision. A growing literature studies behavioral biases in low-income contexts, but relatively few of these focus on inattention in particular (with Hanna et al. (2014) a notable exception). We also investigate

this is beyond the scope of this paper, and we assume this is fixed in the short run.

[17]This is a reasonable assumption in the utilization of household appliances such as cookstoves, refrigerators, and lightbulbs, where hours of usage are largely unresponsive to energy prices.

the micro-foundations of time inconsistency, which has been documented to affect technology adoption (Mahajan and Tarozzi 2011; Dean and Sautmann 2019; O'Donoghue and Rabin 1999). In line with many of these papers, we find that WTP is lower but the impact of credit is larger among agents exhibiting time inconsistency.

We also build on a large body of research studying energy efficiency adoption, which has sought to quantify and decompose the energy efficiency gap (Gillingham and Palmer 2014; Allcott and Greenstone 2012; Christensen et al. 2019). Sometimes engineering models simply overestimate potential savings (Burlig et al. 2019; Davis et al. 2018; Fowlie et al. 2018). Even when energy efficient technologies generate high returns, agents may still under-adopt—this may be due to economic constraints such as credit constraints, information asymmetry, or principal-agent misalignment (Davis 2012; Myers 2015), or behavioral biases. In particular, numerous papers in high-income contexts have attempted to assess whether individuals pay attention to future savings. Busse et al. (2013), Houde and Myers (2019), Myers (2019), Sallee et al. (2016), and Hausman (1979) find evidence that households appear to be discounting rationally, while others like Allcott and Taubinsky (2015), Allcott and Wozny (2014), Gillingham et al. (2019), Jessoe and Rapson (2014), and De Groote and Verboven (2019) find evidence of inattention. We are to our knowledge the first paper use experimental methods to quantify and fully decompose the energy efficiency gap. We are also among the first to generate experimental evidence on barriers to household adoption of energy efficient technologies in a low-income context (together with, for example, Carranza and Meeks (2018), Davis et al. (2018), and Figueroa et al. (2019)).

Finally, we build on an extensive literature studying optimal policy in the presence of environmental externalities. While Pigovian taxation is optimal in an efficient setting (Pigou 1920), little is known about the efficacy of these policies in the presence of credit constraints, which are common in low-income contexts. Second-best policies in the presence of market failures such as market power, principal-agent misalignment, and political constraints have been investigated by a relatively large body of literature (see Fullerton and Wolverton 2005; Knittel and Sandler 2018; Baumol 1972; Fowlie et al. 2016; Myers 2015; Davis 2012; Sallee 2019; Meckling et al. 2017; Jenkins 2014; Goulder and Parry 2008; Fullerton 1997, and many others), but this literature focuses primarily on the U.S. Limited work has studied how credit constraints affect the diffusion of energy efficient technologies, likely because these tend not to be binding for higher-income households.[18] We contribute to the longstanding debate about taxes versus subsidies (Weitzman 1974; Allcott et al. 2015) by arguing that technology subsidies can achieve higher welfare gains than Pigovian taxation alone in credit

[18] Allcott and Greenstone (2012) note: *"There is not much empirical evidence [of credit constraints] in the context of energy efficiency, so we will not discuss it further."*

constrained settings. From a technology diffusion perspective, the full realization of the potential gains for emissions reductions from modern energy efficient technologies requires the widespread diffusion beyond initial adopters (Giaccherini et al. 2019; Barreca et al. 2016; Caselli and Coleman II 2001).

The rest of this paper proceeds as follows. Section 2 provides background on charcoal consumption in Kenya and the energy efficient stove that we study. Section 3 presents a model of household technology adoption and provides a number of testable predictions. Section 4 then presents the experimental design and methodology we use to elicit key behavioral and economic parameters and test this model. Section 5 presents the results. Section 6 considers the aggregate welfare implications of stove adoption and Section 7 discusses the implications of our results for optimal policy. Section 8 concludes.

2 Background: Charcoal use and spending in Kenya

Traditional charcoal cookstoves are costly to low-income households, produce indoor air pollution that contributes to millions of deaths each year, and contribute to growing deforestation and climate change.[19] Many Kenyans use a traditional charcoal *'jiko'* ('stove') for cooking on a daily basis.[20] While middle-income Kenyans have begun to adopt modern cooking technologies, adoption among lower-income households remains low. In this study, we focus on low-income households living in informal settlement areas around Nairobi, where *jikos* are common and charcoal is widely available. For these households, the most salient feature of modern cookstoves are their financial savings.

2.1 Energy expenditures

Total spending on firewood and charcoal in Sub-Saharan Africa in 2012 was USD 12 billion (Bailis et al. 2015). Kenya's charcoal industry grew at 5 percent per year (Food and Agriculture Organization of the United Nations 2017) in the past decade alone, and charcoal usage is expected to grow in the coming decades due to rising incomes and rapid urbanization. Households that currently gather firewood for cooking are likely to climb up the energy ladder and switch to charcoal (Hanna and Oliva 2015). By 2030 fully half of Africa's population is expected to be living in cities, where gathered firewood is not generally accessible, and in

[19]See for example World Health Organization (2017), Center (2014), Pattanayak et al. (2019), and Bailis et al. (2015).

[20]While usage of *jikos* is widespread, statistics are imprecise because many stoves are locally produced, and households often operate multiple cooking technologies simultaneously. Around ten percent of Kenyan households use a *jiko* as their primary cooking technology, with the primary alternatives being traditional stone fires (in rural areas) or gas and kerosene stoves (in urban areas).

many African countries more than 80 percent of the urban population relies on charcoal for daily cooking and heating needs (Food and Agriculture Organization of the United Nations 2017).

The share of household income that is spent on energy costs, also known as the ***energy burden***, tends to be largest among the poor. Within the U.S., energy spending comprises 3.5 percent of household income for the median American household but exceeds 7 percent for the poorest Americans (Drehobl and Ross 2016). The share in low-income countries is even higher—the energy burden for the median household in our study sample is up to 20 percent of household income.

Household adoption of energy efficient appliances has the potential to reduce these expenditures meaningfully—but adoption remains low. The International Energy Agency (2018) estimates that cost-effective energy efficiency opportunities available today to households globally have the potential to save USD 201 billion ***per year*** in avoided expenditure on fuels such as electricity and gas by 2040, as well as another USD 365 billion in transport costs. In total, their forecasts attribute 44 percent of total global emissions reductions by 2040 to energy efficiency gains.

2.2 Charcoal spending

Around two-thirds of households in our sample purchase charcoal at least once per day. The total savings derived from adoption of an energy efficient technology often depend linearly on the price of its energy input. In Kenya, the price of charcoal has fluctuated in recent years, due to the off-and-on implementation of bans on deforestation by the government of Kenya for environmental reasons. Charcoal is almost always sold in small metal or plastic tins ('mkebe' or 'kasuku'), which contain between 1-4 kilograms of charcoal and retail for between USD 0.50 - USD 1.50, although respondents report that the price of charcoal can fluctuate by up to 20-30% of the maximum price on a monthly basis.

2.3 Negative health and environmental impacts of cookstoves

Traditional cookstoves are harmful for health. In 2012 alone, 4.3 million deaths (7.7 percent of all deaths) were attributable to household indoor air pollution (World Health Organization 2014). ***'Respiratory infections'*** is the single largest cause of death in low-income countries, and indoor air pollution is among the largest risk factors for these infections. A household using a charcoal stove as its primary cooking technology typically experiences PM_{10} concentrations of 500 micrograms per m^3 inside the home, which exceeds the U.S. Environmental Protection Agency's ***'hazardous'*** level.

Charcoal usage also contributes to global deforestation. Of the 3.7 billion m^3 of wood extracted from forests worldwide in 2015, 1.9 billion m^3 (50 percent) was used as fuelwood or charcoal. In Africa this was 90 percent (FAO 2017). Kenya in particular is expected to lose 65 percent of its forest cover to charcoal production and use by 2030 (Onekon and Kipchirchir 2016). Between 1—2.4 gigatons of CO_2-equivalent greenhouse gases[21] are emitted annually in the production and use of firewood and charcoal, which is 2—7 percent of global anthropogenic emissions (FAO 2017). Woodfuels comprise 9 percent of global primary energy consumption (Bailis et al. 2015).

A large literature has studied this problem in an effort to identify and increase adoption of stoves that provide meaningful health benefits (see for example Pattanayak et al. 2019, Hanna et al. 2016, Levine et al. 2018, Mobarak et al. 2012, Miller and Mobarak 2013, Burwen and Levine 2012, Beltramo and Levine 2010, Chowdhury et al. 2019). While some research has found positive impacts on self-reported health outcomes (notably, Bensch and Peters (2015, 2019)), many find low demand for improved cookstoves, and limited health benefits among adopters of improved stoves. These results can often be attributed to incorrect engineering estimates, improper stove use or maintenance, or concurrent use of a traditional cookstove (also known as fuel stacking). As countries like Indonesia, China, and India roll out nationwide cookstove modernization projects, non-experimental evidence points to potentially large health gains (see for example Bharati et al. 2018; Zhao et al. 2018).

Cookstoves have been studied less in the context of the energy efficiency literature, which focuses primarily on financial benefits. For example, Hausman (1979) states, *"Some appliances, such as household stoves, offer little possibility of substitution between higher capital costs and lower operating costs."*

2.4 The energy efficient cookstove

We study the Jikokoa stove, produced by Burn Manufacturing ('Burn') at their factory located on the outskirts of Nairobi, Kenya. Burn sells more cookstoves annually in East Africa than any other company. As of June 2019, they had sold more than 600,000 energy efficient cookstoves since their launch in 2013. More than 98 percent of respondents in our sample had heard of the stove, primarily via television (66 percent). 30 percent of respondents had heard about the Jikokoa from a friend, neighbor, or family member; 20 percent had heard about it on the radio; and 10 percent of respondents had seen an advertisement, for example on a billboard, painted on a matatu (bus), or in a newspaper. The Jikokoa was available for

[21] CO_2-equivalent is a standardized measure of the impact of different greenhouse gases, including for example methane (CH_4) and nitrous oxide (N_2O), according to their relative potential contribution to climate change.

USD 40 in stores and supermarkets across Nairobi for the duration of our study.[22] Figure 1 displays a traditional charcoal *jiko* as well as the energy efficient stove we study.

[Figure 1]

The Jikokoa and the traditional *jiko* both use charcoal, and the process for cooking meals using each stove is nearly identical. The primary difference is that the main charcoal chamber of the energy efficient stove is constructed using improved insulating materials. The combustion chamber is made of a metal alloy that better retains heat, and a layer of ceramic wool insulates the combustion chamber to cut heat loss. All parts are made to strict specifications, and components fit tightly to minimize air leakage. These features have been designed and tested extensively by laboratories in Nairobi and Berkeley, which estimated that they provide double the charcoal-to-heat conversion rate of a regular Kenyan *jiko*. Using the energy efficient stove, only half the charcoal would therefore be required to reach and maintain the same cooking temperatures as the traditional *jiko*. To prevent any information asymmetries prior to the start of surveying, all respondents received a pamphlet containing information about the energy efficient stove and its financial savings, which was accessible to literate and illiterate respondents, presented in Figure A1.

Importantly, adoption of the energy efficient stove does not require any behavioral adaptation. The steps required for cooking are identical, and most adopters continue cooking the same types and quantities of food as before.[23] Both stoves use the same type of charcoal, so users can continue to purchase charcoal from their preferred charcoal vendors. Switching to the modern stove does not require any learning, as evidenced by one respondent, who began cooking lunch with the improved stove upon adoption, while the survey was still in progress. When asked an open-ended question about the best features of the energy efficient stove, 87 percent of respondents state financial savings, while only 52 percent state reduced smoke and 22 percent state time savings. Figure A2 displays respondents' beliefs about the benefits of the Jikokoa stove. The stove's charcoal savings are almost twice as salient as any other attribute.

It is possible that other non-financial differences affect adoption, but these would bias us towards underestimating under-adoption. The energy efficient stove improves upon the traditional *jiko* along most stove attributes, including taste, health, time use, durability, and ease of use. Most respondents believe that the energy efficient stove would reduce smoke and improve health, and that food may taste better. The median respondent in our

[22] Since the end of our study, Burn has released a new model of their Jikokoa, sold for only USD 30.

[23] Respondents report improvements in food quality, but this is primarily enabled by savings from the stove—not because of any features of the stove.

sample (correctly) believes that the Jikokoa has an expected lifespan of three years. This is three times longer than the lifespan of the *jiko* used by the median respondent in our sample. This limits concerns about quality or information asymmetry as drivers of under-adoption. In addition, any rebound effect caused by income effects or substitution into energy consumption (Borenstein 2015) would cause us to underestimate under-adoption.[24] We therefore define under-adoption of the stove conservatively as purely the financial gap between costs and benefits.

2.5 Credit in Nairobi

Loans are common in this context. According to the Kenya National Bureau of Statistics (2018), 33 percent of households in Nairobi had accessed credit in the preceding year, primarily from a merchant directly (28 percent) or informally, for example through a Chama[25] or from family or friends. In our sample, 86 percent of respondents had borrowed at least once in that period, primarily through a Chama or from family or friends. For all households, in Nairobi County broadly and within our sample, loans primarily served either a subsistence need, a family need (such as a child's school fees), or a business need. 70 percent of respondents participate regularly in a Chama or *merry-go-round*, with payouts generally ranging between USD 10-300. Around half of respondents participate in a Chama that had a payout of at least USD 40, the cost of the stove at the time of the study, and around one-third of respondents had ever taken out a mobile banking loan such as M-Shwari.

That said, most respondents face significant credit constraints. The loans mentioned above are generally used for emergency situations—a respondent may not want to use a loan to fund technology adoption, and instead wish to keep credit available for emergencies. More than one-third of respondents had sought out a loan in the past year and been refused, primarily by a friend or family member or from a commercial bank or moneylender, and more than 50 percent of respondents said they would borrow more if the cost of borrowing was lower. People who had not taken a loan in the past year did not do so largely because they were worried about their ability to pay back the loan. This may be attributable to high local interest rates. For example, M-Shwari charges 7.5 percent for a loan and requires repayment within one month. Loans that are not repaid within one month are automatically re-registered as a new loan, with an additional 7.5 percent interest rate. If a borrower does not repay a loan within 120 days, they are reported to a local credit bureau (Bharadwaj et al. 2019). While their platform in principle allows loan sizes of up to USD 500, the company

[24] See Section 5.5 for a more thorough discussion of the rebound effect in this context.

[25] A Chama is a common Kenyan savings group. All group members contribute a fixed amount to the group in every period, and the sum of all contributions is given to a different group member in each period.

tracks past M-Pesa usage and borrowing behavior to place quantity constraints on individual borrowing. In practice, this means that almost a quarter of our sample would not be able to take out a loan today, even if they wanted to. The median amount available for short-term borrowing was less than USD 20, and less than a quarter of the sample was able to borrow the full cost of the stove if they wanted to.

There appears to be heterogeneity in access to credit by gender, although only 5 percent of our sample (46 respondents) were male, so these statistics may be noisy. Around 96 percent of both men and women in our sample use mobile money services such as M-Pesa. 25 percent of women would not be able to access a mobile money loan if they wanted to today, while this is the case for only 11 percent of men. The median man would be able to borrow USD 38 while the median woman would be able to borrow only USD 10. There may also be unobservable differences, for example if women face social pressure to use credit for household purposes than for her personal purposes, but we are unable to observe this. That said, 68 percent of women and 59 percent of men had not borrowed anything (formally or informally) in the past 12 months, and 34 percent of women and 46 percent of men had been refused a loan in the past year, suggesting that the overall difference in credit constrainedness by gender is likely to be small.

3 A stylized model of adoption with testable hypotheses

A defining feature of the adoption of energy efficient technologies in the absence of credit is the evaluation of the cost of adoption today against the total value of small, repeated payoffs in the form of future energy savings. Consider an agent with unconstrained access to credit at market interest rates deciding whether to purchase an energy efficient technology available at price P_E.[26] A fully attentive and time-consistent agent will adopt the stove if the utility gains exceed the costs:

$$\underbrace{u(c_0) - u(c_0 - P_E + l)}_{\text{Cost of adoption today}} < \sum_{t=1}^{T} D(t)[\underbrace{u(c_t + \psi_t - r_t) - u(c_t)}_{\text{Future benefits of adoption}}] \tag{1}$$

where c_t is the agent's baseline consumption in period t, l is any amount the agent borrows in period zero,[27] $D(t)$ is the agent's time discount function, ψ_t are the savings from the stove,

[26] P_E can be interpreted either as the price of the efficient technology (with the price of the inefficient technology $P_I = 0$), or as the price of the efficient technology relative to that of the inefficient technology.

[27] $P_E - l$ can be considered the down-payment on the loan.

and r_t are loan repayments.[28] The agent's maximum WTP p^* is given by the price that makes them indifferent between adopting and not adopting the technology. Specifically, for a fully attentive agent, maximum WTP p^* is given by:

$$u(c_0) - u(c_0 - p^* + l) = \sum_{t=1}^{T} D(t) \left[u(c_t + \psi_t - r_t) - u(c_t) \right] \tag{2}$$

The agent adopts the technology if $p^* \geq P_E$. The maximum WTP of a risk neutral agent with exponential discounting $D(t) = \delta^t$ and costless access to credit (or access to savings) is given by:

$$p^* = \sum_{t=1}^{T} \delta^t \psi_t \tag{3}$$

We now explore how adoption may deviate from the case without frictions. We first consider how credit constraints and inattention may affect adoption. We then explore two psychological channels through which credit may operate: concentration bias and inattention-driven time-inconsistency.

3.1 Primary determinants: Credit and inattention

We first consider the effects of two drivers that may directly affect adoption: credit constraints and inattention to benefits.

3.1.1 Credit

Credit constraints are often large in developing contexts (see for example Banerjee et al. 2015, Pitt and Khandker 1998, Karlan et al. 2014, Banerjee and Duflo 2014, Mel et al. 2008, Casaburi and Willis 2018, Suri 2011). Define $\bar{C}_i$ to denote the maximum quantity of credit available to agent i in any single period. The agent's WTP[29] is then p^* such that:

[28] The mapping from l into r_t incorporates market lending rates. We assume credit constraints manifest as quantity constraints rather than high costs of credit. This assumption is realistic in our context: for example, M-Shwari regulates credit among low-income customers via quantity constraints while keeping the cost of credit constant.

[29] Our measure $WTP = p^*$ incorporates credit constraints. However, there exists debate in the literature about the use of the term *willingness-to-pay* as opposed to *ability-to-pay* (ATP). Under that framing, one could define $WTP = p^*$ in the efficient case and $ATP = min\{p^*, \bar{l}\}$. When credit constraints bind, the gap between ATP and WTP can be large. This has consequences for the use of WTP in contingent valuation and revealed preference methods to elicit parameters about benefits from technologies and valuations of environmental quality. We discuss this further in Section 7.

$$u(c_0) - u(c_0 - p^* + l) = \sum_{t=1}^{T} D(t)\left[u(c_t + \psi_t - r_t) - u(c_t)\right] \text{ s.t. } l \leq \bar{C} \tag{4}$$

Assuming that marginal utilities at baseline are equal across periods, credit constraints in this model will decrease WTP in the typical way. Agents who can borrow are able to smooth the utility shock of the purchase, which makes the purchase more attractive. With credit constraints this is no longer possible and the agent is able to bear a lower cost. This yields the following prediction.

> **Prediction 1:** When credit constraints bind, access to credit increases WTP:
> $$\frac{\partial p^*}{\partial \bar{C}} > 0$$

3.1.2 Inattention to energy savings

Next we investigate how inattention may affect the agent's decision-making. Due to cognitive constraints, the agent may be unable to attend fully to all meaningful attributes of the adoption decision (Bordalo et al. 2013; DellaVigna 2009). 60 percent of respondents in our sample purchase charcoal at least once per day, at less than a dollar per day. Savings in any given period are therefore likely to be small—often less than USD 0.50 per day—and respondents may be inattentive to aggregate energy savings, over-attending to the significant cost today and neglecting future savings in the case with limited credit.

Inattention to benefits has been widely studied in the U.S. in the context of household decisions about automobiles, appliances, and housing. Busse et al. (2013), Houde and Myers (2019), Myers (2019), Sallee et al. (2016), and Hausman (1979) find that households appear to compare future savings correctly against today's costs, while Allcott and Taubinsky (2015), Allcott and Wozny (2014), Gillingham et al. (2019), Jessoe and Rapson (2014), and De Groote and Verboven (2019) find evidence of inattention towards future energy savings.

There is little evidence about whether households in low-income contexts correctly evaluate these cost-benefit trade-offs. The cognitive stress of being poor may limit bandwidth and impair decision-making (Haushofer and Fehr 2014; Schilbach et al. 2016; Kremer et al. 2019), which might increase the scope for such inattention. On the other hand, technology adoption decisions have higher stakes for households living in poverty, and they may therefore make more careful decisions (Shah et al. 2015; Fehr et al. 2019; Goldin and Homonoff 2013).

An agent may attend differently to costs and benefits of adoption, depending on their particular nature. When energy inputs are strongly correlated with utilization and easily observable (consider using gasoline to operate a vehicle or using charcoal to operate a stove), an agent may already be very attentive to energy savings. On the other hand, when these are weakly correlated or difficult to observe (consider the impact of refrigerator usage on a monthly electricity bill), an agent may be inattentive. This may partially explain diverging results in the relevant U.S.-based literature discussed above. We discuss attention-driven myopia in the domain of costs more in Section 3.2.2 below.

An agent may under-attend to future benefits by a factor $\theta_b \in (0, 1)$. The condition presented in Equation 2 then changes to:

$$u(c_0) - u(c_0 - p^* + l) = \sum_{t=1}^{T} D(t) \left[u(c_t + \theta_b \psi_t - r_t) - u(c_t) \right] \tag{5}$$

This yields the following prediction:

> **Prediction 2:** For an agent with imperfect attention to benefits $\theta_b < 1$, greater attention to benefits θ_b will increase WTP:
>
> $$\frac{\partial p^*}{\partial \theta_b} > 0$$

We are agnostic as to the micro-economic model that generates inattention.[30] As in Gabaix and Laibson (2017), an agent may experience attention-driven ***myopia***—agents may simply experience future benefits on a diminished scale. In this framework, an agent may imperfectly observe future periods, and combine noisy signals about future energy savings with their priors about what these might be, to inform their adoption decision. Alternatively, given that benefits accrue in small amounts over numerous periods, inattention may be driven by ***concentration bias*** (Koszegi and Szeidl 2013), where individuals attend disproportionately to periods where outcomes differ more. We discuss this phenomenon in the context of costs in Section 3.2.1 below—through our experimental design we will be able to test for concentration bias in energy savings and costs independently.

3.2 The psychology of credit

Access to a loan relaxes credit constraints—but it also modifies the structure of costs. It allows costs to be incurred in the future rather than today, and it reduces the maximum cost in any single period. Does access to credit increase adoption solely by addressing credit constraints, or do psychological determinants affect adoption independently by altering the

[30] We explore the micro-foundations of θ_i in more detail in Appendix Section 8.1.1.

perception of costs? We consider two potential channels: concentration bias and inattention-driven time-inconsistency.

3.2.1 Concentration bias

When making decisions, individuals tend to attend disproportionately to periods or attributes with larger variability across their choice set, where the range of impacts on utility (defined as the difference between the minimum and maximum utility outcomes) is larger. An important special case of this is that agents are more likely to attend to periods where the financial consequences of a choice are larger (for example, a down-payment versus installment payments). Individuals might therefore be more likely to prefer payment structures where costs are dispersed across many smaller deadlines (Dertwinkel-Kalt et al. 2019), since this makes total costs less salient.

Koszegi and Szeidl (2013) model this phenomenon by assuming that the utility of a choice c with K attributes from choice set C is a weighted sum over its attributes $U(c) = \sum_{k=1}^{K} g(\Delta_k(C))u_k(c_k)$, where $\Delta_k(C) = max_{c' \in C} u_k(c'_k) - min_{c' \in C} u_k(c'_k)$. Importantly, $g(\cdot)$ is an increasing function—agents pay more attention to an attribute when its impact on utility across the universe of consumption choices C is highly variable. Under this framework, an agent faces the following adoption decision:[31,32]

$$u(c_0) - u\big(c_0 - g(\Delta(p-l))(p^* - l)\big) = \sum_{t=1}^{T} D(t)\left[u\big(c_t + \psi_t - g(\Delta(r_t))r_t\big) - u(c_t)\right] \tag{6}$$

Define N to be the number of periods with $r_t > 0$ (with $1 \leq N \leq T$),[33] and assume all non-zero payments have equal size. Given that $g(\cdot)$ is increasing, for $N_H > N_L$ we have $g(\Delta(\frac{l}{N_H})) < g(\Delta(\frac{l}{N_L}))$ because the possible variation in payment size across loan sizes is smaller with more payments. Thus,

Prediction 3: An agent exhibiting concentration bias will have higher

[31] $g(\cdot)$ here can apply to both benefits and costs. Our experimental design allows us to test explicitly for concentration bias in costs. We test for concentration bias in benefits insofar as the attention intervention incorporates this bias.

[32] For simplicity, because all of the attributes we consider only affect consumption, we depart from Koszegi and Szeidl (2013) and assume that the attribute specific utility functions $u_k(\cdot)$ are linear and that the agent then uses the weighted sum of these in their overall utility function.

[33] If the entire cost is paid up-front, $l = 0$ and $N = 0$. This is relevant for interpreting the psychology of providing credit, but is empirically difficult to distinguish from present bias given that it moves payments away from the present. We therefore restrict our empirical investigation to cases where $l > 0$ and $N \geq 1$.

WTP when total cost is dispersed across a larger number of payments:

$$\frac{\partial p^*}{\partial N} > 0$$

3.2.2 Inattention-driven myopia

Inattention to future costs, or ***myopia***, can result in time-inconsistent behavior. This can be based in different microeconomic foundations. For example, the agent may simply "experience" future utility in a diminished way. They may evaluate costs in future periods by generating noisy signals and combining them with their priors, as per Gabaix and Laibson (2017). Or, it may be that beliefs directly enter the utility function, and the agent experiences disutility from the very acquisition of information about costs itself, causing intentional inattention to costs (Golman et al. 2017). For whatever reason, an agent may be inattentive to future costs by a factor $\theta_c \in (0, 1)$. The adoption decision can then be defined as:

$$u(c_0) - u(c_0 - p^* + l) = \sum_{t=1}^{T} D(t) \left[u(c_t + \psi_t - \theta_c r_t) - u(c_t)\right] \text{ s.t. } l \leq \bar{C} \tag{7}$$

With payment in installments, costs are moved from $t = 0$ to being incurred across periods $t = 1, ..., T$, while benefits across all periods stay the same. For $\theta_c < 1$ this will decrease the value of costs relative to benefits. It follows that,

> **Prediction 4:** The impact of credit on WTP will be smaller among agents exhibiting more attention to future costs:
>
> $$\frac{\partial^2 p^*}{\partial \bar{C} \partial \theta_c} < 0$$

The inattention parameter θ_c might affect the impact of credit in a similar manner to present bias or changing marginal utility in this context. A large literature documents how time-inconsistency affects decision-making, particularly during technology adoption among low-income individuals (see for example Mahajan and Tarozzi (2011), Casaburi and Willis (2018), and Duflo et al. (2011)). The microeconomic foundations of time-inconsistency are subject to ongoing debate. O'Donoghue and Rabin (1999) define present bias as ***"a bias for the present over the future"***, reflecting an agent's true preference for utility today over utility in the future. Present biased preferences can easily be incorporated in the model discussed above with quasi-hyperbolic preferences $D(t) = \beta\delta^t$ with $\beta \in (0, 1)$. Dean and Sautmann (2019) argue that time-inconsistency may arise even in the absence of present bias due to changes in marginal utility across time, u_t. These might result from income shocks or preference shocks, which are in general common in low-income contexts. The primary difference is that an experimental attention treatment may affect θ_c, but would not affect β or u_t since these reflect the agent's fully rational decision. While time-inconsistency cannot be randomly assigned, in our experimental design we measure time-inconsistency using an effort task allocation exercise as per Augenblick et al. (2015). More information on this is provided in Section 4.5.

At an extreme, expanding credit in this model can make the agent worse off due to the neglect of future costs. Since agents do not perceive future costs fully, they will want to over-borrow (Meier and Sprenger 2010) and some amount of credit constraints limits their ability to do so. Participants in this study are likely far from this case.

4 Experimental Design

We enroll 1,018 respondents who live in the Dandora, Kayole, Mathare, and Mukuru informal settlement areas around Nairobi and who currently use a traditional charcoal cookstove. Charcoal is readily available in these areas, with a charcoal seller on every street in most areas.

These areas are among the lowest-income areas of Nairobi, and have not been targeted by sales teams of the cookstove company. Field officers walked around these areas and enrolled respondents quasi-randomly by visiting them at their homes until the required number of respondents had been enrolled. To qualify for study participation, respondents had to use a traditional charcoal *jiko* as their primary cooking technology and spend at least USD 3 per week on charcoal. The median household in our sample contains two adults and two children, earns a daily income of USD 5, and spends USD 0.70 (14 percent of income) on charcoal every day. 60 percent of study participants purchase charcoal at least once per day, at less than one dollar per day. Households buy a new *jiko* around once per year, for between USD 2 and USD 5. 95 percent of respondents in our sample are women, largely reflecting Kenyan societal norms and expectations around household tasks. Table 1 presents summary statistics of additional socioeconomic variables.

[Table 1]

It is worth noting that respondents in our sample have on average significantly lower incomes than existing cookstove adopters. According to two proprietary studies completed by a third-party consultant on behalf of the cookstove company in 2016 and 2017, consisting of phone surveys with a random sample of existing customers, only 12 percent of recent adopters live below the Kenyan poverty line (Ksh 310 per person per day, or around USD

3), while 88 percent of our respondents do. More than half of adopters had attended college or university, while only 5 percent of our respondents have.

4.1 Experimental timeline

The survey design centers around three in-person visits referred to as ***visit 1, visit 2,*** and ***visit 3***, or the ***baseline, midline,*** and ***endline*** visits, respectively. These visits were timed to be 28 days apart.[34] Aside from the visits, during the study period participants complete three additional activities: 1) A recurring SMS survey conducted once every three days that asks about a respondent's charcoal expenditures in each intervening 3-day period; 2) Collection of ash in a bucket to measure physical charcoal usage; and 3) Loan payments, for respondents who purchased the stove and who are in the credit treatment arms. Figure 2 presents the timeline for these components. More detail on each component is provided below.

[Figure 2]

Each respondent receives three in-person visits timed one month apart. During visit 1, the field officer completes the enrolment survey, which includes a series of economic, demographic and health questions. Respondents in the attention treatment groups then start receiving SMSes about their charcoal spending, while respondents in the attention control group receive SMSes about an unrelated topic before switching to the same charcoal SMSes after visit 2. During visit 2, the field officer implements the relevant credit and/or attention treatments that were assigned to this respondent, and then implements the BDM mechanism (see section 4.3 below). If the respondent wins the stove, they receive the stove during visit 2—respondents in the credit control group must also pay the entire amount P_i today. After visit 2, all participants are asked to collect charcoal ash in the bucket provided. In addition, participants who won the stove during the BDM auction and who are in one of the credit treatment groups begin making their weekly or monthly payments (A1 or A2, respectively). During visit 3, the field officer implements the endline survey and weighs the ash collection bucket.

Each respondent was randomly assigned into one of three credit treatment groups and one of three attention treatment groups. They were also assigned a randomized price for the stove—each respondent received a different subsidy relative to the retail price. We describe these procedures in more detail below.

[34] Due to logistical constraints and limited respondent availability due to their work and personal commitments, actual visits deviated moderately from this in practice. 88 percent of visit 2 surveys were conducted between 23-33 days of that respondent's visit 1 survey, and 90 percent of visit 3 surveys were conducted between 23-33 days of that respondent's visit 2 survey.

4.2 Credit and attention: Experimental treatment arms

Based on the model described in Section 3, we implement a 3-by-3 experimental design, cross-randomizing two credit treatments with two attention treatments. Treatment is stratified by baseline levels of charcoal spending. Figure 3 displays treatment assignment for all 1,018 respondents.

[Figure 3]

Respondents in the credit treatment pay an interest rate of $r = 1.16$ percent per month[35] on their loan, which is automatically factored into their payments. Respondents who were not able to make their payments were asked to return the stove.[36] Regardless of the credit treatment group to which they were assigned, every respondent who purchased the stove received it during visit 2.

> **Credit control group (C0):** Individuals are required to pay 100 percent of the price of the stove at the time of visit 2.
>
> **Weekly payments (C1):** Participants may pay for the stove by 12 weekly deadlines, starting one week from visit 2. They may pay more frequently or earlier, as long as they meet the cumulative minimum by each weekly deadline.
>
> **Monthly payments (C2):** Participants may pay for the stove by three 4-weekly deadlines, starting 4 weeks from visit 2. They may pay more frequently or earlier, as long as they meet the cumulative minimum by each monthly deadline. For example, respondents in this group may pay in weekly instalments if they choose.

The difference in WTP between C0 and {C1,C2} provides a test of Prediction 1, pertaining to credit constraints yielded by Equation (4). The difference in the cost streams of C1 and C2 allows us to test Prediction 3 pertaining to concentration bias, as per Equation (6). While the formal model does not consider cost of credit or the cost of default, the credit intervention addresses three channels through which individuals may face credit constraints.

[35] This was the borrowing interest rate of M-Shwari (exclusive of fees) at the time of our study.

[36] All respondents received SMSes reminding them of their upcoming payment deadlines in advance. If a respondent missed a deadline, they were initially sent three reminders over a six day period. If they had not paid within one week after their missed deadline, a field officer would visit them and reclaim the stove. As of July 6, 2019, three respondents had returned their stoves, primarily as a result of unexpected health or negative income shocks. More detail on repayment is provided in Section 5.8.

The intervention addresses quantity constraints by not constraining the size of the loan that the agent may take out to pay for the stove. By charging an interest rate that excludes the fees charged by mobile lenders, the intervention reduces the cost of borrowing. Finally, agents do not face any penalties under default. If someone chooses to default on their loan, a field officer will collect the stove, and the agent will face no repercussions to this decision.[37] This departs from the conditions for a loan with many mobile lending providers, who often charge fees for late payments or default, or who pass on information about any instances of default to inform the agent's credit score.

One alternative to this interpretation is that respondents may prefer weekly deadlines due to a demand for commitment rather than a reduced focus on costs (Field and Pande 2008). Since this would increase WTP among respondents in the weekly deadlines group, this would cause us to overestimate concentration bias. To test this concern, respondents in C2 are given the opportunity to switch to weekly deadlines as a commitment device, for example if they believe this will help them make their payments on time. Respondents in C2 are informed of this option before the WTP elicitation, and if they adopt the stove, they make their choice after this is complete. Only 12 percent of respondents offered this commitment device took it, suggesting a demand for commitment would likely not drive a preference for weekly over monthly deadlines.[38]

To test for inattention, we cross-randomize these credit treatments with two treatments designed to increase attention:

> **Attention control group (A0):** Participants are informed that the stove manufacturer says that the stove can be expected to reduce charcoal consumption by 50 percent. They are informed of the Ksh equivalent of these savings, based on the respondent's stated weekly charcoal spending. They are also given a calculator, and are allowed to use it to perform calculations regarding their expected savings if they choose.
>
> **Attention to energy savings (A1):** Participants receive everything that A0 receives. In addition, in the month between visit 1 and visit 2, respondents are asked about their charcoal spending every three days via SMS.[39]

[37] In a modest number of cases, the agent defaulted and field officers were unable to find the respondent to hold them accountable for repayment. The agent may have moved or changed their phone number to avoid repayment. The research team does not have authority to implement any penalties or legal repercussions, other than repeatedly attempting to contact the participant to encourage repayment.

[38] The lack of interest in switching to a weekly payment plan may reflect a preference for the flexibility of a monthly payment schedule. Field et al. (2012) find that micro-finance clients in India paying on a monthly payment schedule were 51 percent less likely to be worried about repayment. Their study design does not allow them to study differences in take-up across these payment schedules.

[39] To ensure that contact with the research team was constant across all participants, respondents in the

Further, before the BDM elicitation in visit 2, the enumerator assists[40] them in filling in an attention sheet, writing down the amount of money they think they would save each week for the next year if they owned an energy efficient stove. This can be expected to be around 50 percent of their expected spending each week, with larger savings during weeks when the participant expects to spend more on charcoal for cooking, for example during religious holidays, or when a temporary migrant returns home. Figure A3 shows the attention sheet. The enumerator then assists the individual in summing up the expected savings for each of the twelve months, and asks them to think about and write down how they could use these savings for each month. Respondents are then given a ***waiting period***[41] of 5 minutes to think about these savings while the enumerator enters the numbers into a tablet. The savings are then shown on the tablet during the BDM elicitation.

Attention to energy savings minus costs (A2): Participants receive everything that A1 receives. In addition, during the BDM they are informed of the cost during each period, alongside the savings in each period as listed in their attention sheet. The cost per period is calculated and presented in line with the respondent's credit treatment group (C0, C1, C2). The net benefit (defined as cost - savings) for each period is also calculated and presented to the respondent.

The difference between $A0$ and $\{A1, A2\}$ corresponds to the attention to savings θ_s modeled in Equation (5), while the difference between $A1$ and $A2$ corresponds to attention to costs θ_c modeled in Equation (7). This setup thus provides a test for Predictions 2 and 5.

One may be concerned that the attention treatment addresses math ability or provides awareness of the technology rather than addressing attention alone. To alleviate this concern, respondents complete a short math test consisting of eight questions taken from Kenya's Certificate of Primary Education (KCPE) and Secondary Education (KCSE) standardized exams. This allows us so test for heterogeneity in the attention treatment by math ability.

attention control group received placebo SMSes between visits 1 and 2. The timing and incentives were identical, but respondents were asked about their matatu (bus) travel instead of their charcoal expenditures. Starting at visit 2, these respondents were moved into the regular charcoal SMS survey.

[40] 47 percent of respondents were able to fill in the sheet entirely independently. 31 percent of respondents were able to write in most of the sheet independently, but required some guidance by the field officer. 22 percent of respondents were illiterate and the field officer had to fill in their attention sheet on their behalf.

[41] Recent work has shown that a *waiting period*, defined as a delay between information about a prospective choice and the choice itself, can lead to more forward-looking choices. For example, Brownback et al. (2019) find that a waiting period causes a 28 percent increase in healthy food purchases.

In addition, nly 10 people had ***not*** heard of the Jikokoa stove at baseline, so we are unable to test whether the attention treatment works more effectively for respondents that were not aware of the technology at baseline, but given the low baseline levels of unawareness it is unlikely that this would be a meaningful channel.

4.3 Becker, DeGroot, Marschak (BDM) mechanism

We implement the Becker, DeGroot, Marschak (BDM) mechanism defined in Becker et al. 1964. The BDM mechanism serves two purposes. First, because the mechanism is incentive compatible, respondents should truthfully state their WTP for the energy efficient cookstove. Second, because P_i is randomly assigned, adoption of the stove is random conditional on WTP. This randomized stove assignment allows us to estimate the causal impact of cookstove adoption on charcoal spending.

Implementation of the BDM mechanism builds on the methodology developed in Berry et al. (2020) and Dean (2019) and proceeds as follows: each respondent is first randomly allocated a hidden price P_i. This price is printed and placed inside a closed envelope with the respondent's name on it prior to the start of the survey. Neither the respondent nor the field officer implementing the survey knows the price.

The field officer and the respondent then use a binary search algorithm over the interval USD 0 to 50 to determine the respondent's maximum WTP. The respondent is asked 12 binary questions asking whether they would purchase the stove for a given price. Question 1 for every respondent asks, *"If the price of the Jikokoa is 2,500 Ksh [USD 25] would you want to buy it?"* The subsequent question then asks about the mid-point of the remaining interval and so on. For instance, if the respondent answers *'yes'* to question 1, the next question will be, *"If the price of the Jikokoa is 3,750 Ksh [USD 37.50] would you want to buy it?"* Conversely, if the respondent answers *'no'* to question 1, the next question will be, *"If the price of the Jikokoa is 1,250 Ksh [USD 12.50] would you want to buy it?"*

The binary questions incorporate each respondent's credit treatment assignment. A participant in the weekly payments credit treatment group might be asked, *"Would you be willing to pay Ksh 2,000 [USD 20] for the stove? You would pay Ksh 169.67 [USD 1.70] per week for the next 3 months,"* and a participant in the monthly payments credit treatment group might be asked, *"Would you be willing to pay Ksh 2,000 [USD 20] for the stove? You would pay Ksh 682 [USD 6.82] per month for the next 3 months."* The conversion from total amount to weekly or monthly payments incorporates the interest rate of 1.16 percent per month. The information presented will also vary based on which attention treatment the respondent is in. Respondents in A1 will see the savings they wrote down next to the BDM price they are considering at that moment. Respondents in A2 will see the savings they wrote down, the costs, and the net benefits corresponding to the BDM they are considering at that moment. As the binary questions vary, the costs in each period and net benefits are calculated and updated accordingly. Figure A4 provides examples of the screen for three hypothetical respondents. The full script can be found in subsubsection 8.1.2.

Benefiting from the law of exponents, after answering 12 binary questions, the respondent has disclosed their maximum WTP to the nearest USD 0.01. After respondent i has stated their maximum WTP_i, the respondent and the field officer then open the envelope containing the hidden price P_i. If $WTP_i < P_i$, the respondent is not allowed to purchase the stove. If $WTP_i \geq P_i$, the respondent must[42] purchase the stove today. It is important to note that the decision on WTP is binding, and naming a WTP on either side of the threshold where $WTP_i = P_i$ therefore has meaningful consequences. To ensure that the respondent understood the consequences of their decision, field officers performed an extensive series of checks and confirmation questions. For example, field officers asked respondents to describe what would happen if $P_i = WTP_i + 5$ (the respondent would not be able to purchase the stove today) and if $P_i = WTP_i - 5$ (the respondent would purchase the stove for P_i) numerous times throughout the process. In the final question, asked immediately prior to opening the envelope, 97 percent of respondents answered both questions correctly.[43] In addition, each respondent played a practice BDM round with a small item (either a bar of soap or a bottle of hand lotion) prior to the cookstove BDM. We provide more information about this below.

The distribution of BDM prices P_i that would generate the strongest first stage in the subsequent instrumental variables regression would be the one where each respondent was assigned a price of either USD 0 or USD 40, as this would ensure perfect randomization—treatment assignment would be entirely independent of WTP. We depart from this distribution to satisfy several goals. First, to reduce attrition, we want all participants to receive a discount of at least USD 13 relative to the retail price. Second, for cost reasons, we want most respondents to have a subsidy of no more than USD 30. However, to ensure wide demographic heterogeneity and to be able to meaningfully test for heterogeneous effects by WTP, we want a small subset of subjects to have subsidies that exceed USD 30. Third, to ensure incentive compatibility, such that every participant has an incentive to state their true WTP, all prices across the distribution [0.01, 29.99] must have a positive probability.

[42] Despite extensive training and repeated response verification, 8 of the respondents for whom $WTP_i \geq P_i$ (1.4 percent) were ultimately not able to pay P_i for the stove. We did not force these respondents to adopt the stove, and we interpret this econometrically as imperfect compliance with treatment assignment.

[43] Furthermore, 10 percent of respondents for whom $WTP_i < P_i$ argued when they saw the price—in the majority of these cases, the argument concerned the high price (the respondent wanted a larger discount) rather than miscomprehension about the process itself.

Finally, to preserve the unpredictability of prices for field officers, so as to avoid unwarranted interference or assistance prior to the opening of the envelope, we want to draw prices from a narrow uniform distribution around each mass point rather than assigning the center itself.

These specifications result in the following distribution. Six percent of participants are allocated a USD price drawn from $U[3.50, 4.50]$, 39 percent of participants are allocated a price drawn from $U[10, 12]$, 44 percent of participants are allocated a price drawn from $U[25, 27]$, and 11 percent of participants are allocated a price drawn from the entire interval $U[0.01, 29.99]$. Figure A5 displays the resulting distribution of BDM prices for all 1,018 participants. Prices were randomly assigned to participants after visit 1 and are stratified on baseline levels of charcoal consumption and on assignment to the attention and credit treatments.

Prior to the start of the BDM each respondent completes two practice exercises, one for a bottle of lotion (valued at USD 1.20 in stores) and one for a bar of soap (valued at USD 1.50 in stores), displayed in Figure A6. Each respondent is allocated a random price $P_L \sim N(0.74, 0.35)$ for the lotion, truncated at USD [0.01, 1.10], and a random price $P_S \sim N(0.89, 0.42)$ for the soap, truncated at USD [0.01, 1.30], reflecting their respective retail prices.[44] 50 percent of respondents were first given their randomly assigned price as a take-it-or-leave-it ('TIOLI') offer for purchasing the lotion, and were then asked to complete a practice BDM exercise with the soap. The remaining 50 percent first responded to a TIOLI offer for the soap and then completed a BDM exercise with the lotion.[45] The full script for the TIOLI and BDM practice rounds can be found in subsubsection 8.1.2.

These two take-up decisions served two purposes. First, participants get an opportunity to better understand how the BDM mechanism works relative to a standard TIOLI that they are used to in stores. In particular, they experience the binding outcome of the bidding process. Second, a comparison of the demand curves generated using the two mechanisms provides a natural test of the validity of the BDM mechanism in this setting. Figure A7 displays the demand curves elicited through the TIOLI and BDM mechanisms for both goods. The overlap suggests that respondents understand the BDM mechanism and that the elicited WTP values reflect realistic decisions.

[44] On the first three days of implementation, the practice prices for the lotion and soap were lower, averaging around USD 0.47 and USD 0.51 respectively. Because of higher than expected demand for both products, we increased prices to the higher amounts starting on the fourth day.

[45] Ideally we would have also been able to counterbalance the order of the TIOLI and BDM practices. We decided the potential for additional confusion by separating the BDM practice from the cookstoves BDM outweighed any potential benefit from ruling out order effects.

4.4 Measuring charcoal use

We use three independent methods to measure charcoal use. The primary outcome is a recurring SMS survey. Every three days the respondent receives an SMS asking how much money they spent on charcoal in the past three days. To increase response rates, respondents receive a reward of USD 0.20 for every SMS that they respond to, regardless of the content of their SMS, as well as a bonus of USD 2 for every 10 SMSes that they correctly respond to. Second, during the endline survey, we ask respondents to recall their recent charcoal expenditures.

Finally, to generate ground-truth comparisons of these self-reported measures of charcoal use and address any concerns around experimenter demand or Hawthorne effects, respondents collect the ash generated by cookstove usage between the second and third visits. Normally, when a respondent is done cooking a meal, they dispose of the charcoal ash in the trash. Instead, during visit 2, each respondent is given an empty 20 liter bucket and asked to dispose of the used ash in the bucket rather than in the trash. During visit 3, field officers weigh the bucket using a hand-held weighing scale.

4.5 Measuring time-inconsistency

To understand how time-inconsistency affects adoption decisions and the impact of credit as per Predictions 5 and 6, we measure time-inconsistency through an effort task allocation exercise.[46] Since money is fungible across time, the marginal propensity to consume may not correlate strongly with instantaneous payouts and preferences between different streams of monetary benefits may not reflect intertemporal preferences over utility (O'Donoghue and Rabin 2015; Cubitt and Read 2007; Dean and Sautmann 2019). We therefore elicit preferences over instantaneous utility, following the methods and implementation strategy developed in Augenblick et al. (2015). We adapt the exercise for our context so that it can be completed in a field setting. The effort task we employ consists of counting the number of times a triangle, circle, and cross appear on a grid. Figure A8 displays an example of an effort task. Respondents on average took one to two minutes to complete one effort task.

Respondents first complete three practice effort tasks during visit 1 to understand the procedures and the cost of effort. They are then informed that they will need to complete additional tasks during visits 2 and 3. They are told they will have the opportunity to choose when and how many of these tasks they will need to do.

[46] As per the model described in Section 3, we allow time-inconsistency to be caused by either an innate preference toward the present (the β present bias as defined in the $\beta - \delta$ model) or inattention to future benefits or costs θ_b, θ_c.

During both visit 1 and visit 2, respondents decide how many of those tasks they would like to do in visit 2 and how many in visit 3.[47] During visit 1, decisions about both visit 2 and visit 3 are in the future. In contrast, during visit 2, the decision about visit 2 tasks is in the present while the decision about visit 3 is in the future. Since the relative temporal distance between visits 2 and 3 does not change, any difference between the decisions made during visit 1 and the decisions made during visit 2 is evidence of time-inconsistent behavior. Respondents who choose to postpone additional tasks during visit 2 relative to their decisions in visit 1 are thus classified as exhibiting time-inconsistency using a binary indicator. Using this methodology, 57 percent of respondents are classified as exhibiting time-inconsistency.

4.6 Measuring risk preferences

To measure risk aversion, we follow Gneezy and Potters (1997) and Charness et al. (2013). At the end of visit 1, each respondent is offered a thank you appreciation of USD 4 for their time that day. Respondents are then told that they can now participate in an investment game, as follows. They first choose any amount $x \in [0, 4]$ to invest. They then (blindly) pick one of two pieces of paper from a small bag. If the paper says ***'Win'***, they receive 3x the amount they invested. If the paper says ***'Lose'***, they lose the amount that they invested. Regardless of the outcome of the invested amount, respondents always receive the amount that was not invested $(4 - x)$. The expected payoff X of an investment x is given by:

$$E[X] = [4 - x] + [\frac{1}{2} \cdot (0) + \frac{1}{2} \cdot (3 \cdot x)]$$

A profit-maximizing risk neutral individual invests $x = 4$. An investment of any amount $x < 4$ can be interpreted as risk aversion. In our sample the 25th, 50th, and 75th percentiles of x equal USD 0.50, USD 1, and USD 2 respectively. Respondents who choose to invest $x < 2$ (68 percent) are classified as exhibiting risk aversion.

4.7 Measuring beliefs about health

We build on existing methodologies from the cookstove health literature (Usmani et al. 2017; Hooper et al. 2018) to elicit baseline levels of health as well as beliefs about the impacts of stove adoption on health. We first ask a series of binary questions about recent respiratory symptoms experienced by the primary cookstove user and any children living in the home. We then ask a series of Likert-scale questions eliciting beliefs about the extent to which

[47] To limit the potential relevance of any fixed costs in the exertion of effort, all respondents must complete at least three tasks in each visit.

usage of a traditional stove specifically has had negative impacts on their health, and how much adoption of an energy efficient stove might improve their health. We combine these measures into two indices for levels of health and beliefs about health improvements from energy efficient cookstove adoption.

5 Results

We now present the results. Section 5.1 estimates the financial savings from stove adoption, and compares these returns with relevant alternative investments that our respondents may have access to. Section 5.2 presents the demand curve for the control group corresponding to the elicited WTP, and quantifies under-adoption by comparing WTP with the financial returns. Finally, sections 5.3 and 5.4 investigate how credit and psychology affect under-adoption.

Table A1 presents balance checks for the randomized credit, attention, and subsidy treatment assignments,[48] for key demographic and socioeconomic variables. None of the joint F-tests are significant. Assignment of all three treatments appears to be balanced on key economic and demographic characteristics. Figure A9 displays a map of the distribution of respondents and their randomly assigned treatments across Nairobi, Kenya.

5.1 The energy efficient technology has large returns

Figure 4 presents weekly charcoal spending before and after the main visit, for adopters and non-adopters of the energy efficient stove, as elicited through the SMS survey. Spending appears to decrease sharply immediately after adoption, by around USD 2, and this difference appears to be stable for at least two months after adoption.

[Figure 4]

To estimate the causal effect of adoption of the energy efficient charcoal cookstove on household charcoal spending, we employ an instrumental variables approach. In the first stage we use the randomly assigned BDM price P_i as an instrument for stove ownership d_i. 576 respondents adopted the stove (60 percent), out of the 962 respondents who completed visit 2. In the second stage we regress weekly charcoal spending y_i on the predicted value of stove ownership $\hat{d}_i$. Because P_i is randomly assigned, this regression identifies a causal effect. Econometrically, this proceeds as follows:

[48]For the subsidy treatment balance check, we define treatment as BDM price $P_i \leq$ USD 15 (50 percent of respondents).

$$d_i = \gamma_0 + \gamma_1 P_i + \gamma_2 X_i + u_i$$

$$y_i = \beta_0 + \beta_1 \hat{d}_i + \beta_2 X_i + \epsilon_i$$

We estimate the impact on charcoal spending y_i in USD and in percentage terms. To accommodate values of 0 in charcoal spending, we use an Inverse Hyperbolic Sine (IHS) transformation instead of the standard natural logarithmic transformation, as described in Burbidge et al. (1988).[49,50]

Table 2 presents the results. In the first stage presented in Column (1), the BDM price strongly predicts stove adoption. Columns (2) and (3) show that the stove reduces charcoal spending by USD 2.28 per week on average, or a decrease of 50 log points, which corresponds to a 39 percent decrease in charcoal consumption. Table A2 confirms that these results also hold for self-reported weekly charcoal spending during the endline survey. Using data from a pilot experiment conducted in Fall 2018, Figure A10 confirms that these causal impacts are stable over time, up to 18 months after adoption.

[Table 2]

Column (4) shows that stove adoption causes a 39 percent reduction in total ash generated between visits 2 and 3. This estimate matches the (entirely independent) estimate from the SMS data, lending confidence to these results. Converting 'weekly charcoal spending' (in Ksh) to 'kilograms charcoal purchased' (in KG) using local charcoal market prices, and comparing KG of charcoal purchased with KG of ash generated from charcoal usage, identifies a charcoal-to-ash conversion ratio of 1.6 percent (with a 90 percent confidence interval of 1.3—1.9 percent). This falls within accepted estimates of the physico-chemical properties of charcoal (FAO 1987), again lending confidence to the use of ash generation as a proxy for charcoal usage.

It is worth putting the size of these savings into perspective. USD 2.28 per week—USD 119 per year—corresponds to on average one month of respondent income.[51] Net Present Value[52] (NPV) after two years of stove ownership equals USD 178 per respondent, and is positive for $>$ 99 percent of respondents.[53] Given the low levels of baseline consumption

[49]The IHS is defined as: $sinh^{-1}(x) = log(x + (x^2 + 1)^{1/2})$.

[50]Table A2 confirms that the results are similar when dropping the zeros and using the natural logarithmic transformation instead of the IHS transformation.

[51]The 10th, 50th, and 90th percentiles of these savings are equivalent to 3.6, 9.1, and 21.2 percent of respondent income, respectively.

[52]We define $NPV_i = \left[\sum_{t=1}^{T} D(t)\psi_{it}\right] - P_E$, where $D(t) = \delta^t$ and $\psi_{it} = \gamma\hat{s}_i$ as in Equation 2. We use $\delta = 0.9$ annualized, $P_E = 40$ USD, $\gamma = 0.39$ savings as estimated above, and with $\hat{s}_i$ equal to each respondent's post-adoption counterfactual charcoal spending, over $T = 104$ weeks post-adoption.

[53]Figure A11 displays the full distribution of NPV across all respondents.

among respondents (and assuming concavity of $u(x)$), the marginal utility from these savings is likely to be large. When asked how they spent their charcoal savings, 53 percent of respondents report buying more food, 23 percent report paying school fees, and 15 percent report buying household items such as soap or clothes.

Our empirical estimate aligns closely with ex-ante engineering predictions. The stove manufacturers[54] previously estimated that the efficiency gain from the Jikokoa stove is 43–45 percent relative to a traditional Kenyan stove. Our point estimate is a 39 percent reduction with a 95 percent confidence interval of (30, 48). We therefore cannot rule out that the engineering estimates accurately predict realized savings. This is in contrast to extensive existing empirical work evaluating energy efficiency investments, which finds realized savings lacking when compared to engineering estimates (see Fowlie et al. (2018), Burlig et al. (2019), Allcott and Greenstone (2017), and Gillingham and Palmer (2014) for examples), although it is worth noting that much of this evidence comes from high-income settings (with the exception of Davis et al. (2014)). The correspondence between the engineering estimates and our empirical findings may be due to the limited scope for rebound in this setting,[55] the homogeneity of the technology, and the simplicity of its implementation.[56]

Relative to a retail price of USD 40, these savings constitute an average internal rate of return (IRR)[57] of 24.7 percent per month, or 296 percent per year.[58] This is larger than almost all available alternatives. Indeed, for a credit constrained household, the relevant metric to inform the adoption decision is the IRR ***relative to available alternatives***. Table 3 places this estimate in the context of the existing literature.

[Table 3]

The IRR on the energy efficient cookstove is an order of magnitude larger the IRR of most relevant alternative investments that are available to respondents in the domains of enterprise, agriculture, and education. Recent papers in the U.S. have even found ***negative*** IRR for such household investments.

[54] This research was implemented in conjunction with the Berkeley Air Monitoring Group and the University of Washington.

[55] We discuss the rebound effect further in Section 6.6.

[56] Christensen et al. (2019) provide an analysis of what may drive the wedge between projected returns in energy efficiency programs.

[57] The IRR corresponds to the discount rate where the Net Present Value of an investment, from time 0 to infinity (we assume two years of use), equals 0. Specifically, IRR equals δ such that $\left[\sum_{t=1}^{T} \delta^t \psi_t\right] - P_E = 0$.

[58] Conversion between monthly and annualized IRR conservatively (and in line with the literature) assumes no reinvestment.

5.2 Under-adoption is large

As in Equation 2, a, risk-neutral agent facing no credit constraints[59] or other market failures, and with no behavioral biases will have a maximum WTP of $p^* = \sum_{t=1}^{T} D(t)\hat{\psi}_{it}$, where $\hat{\psi}_{it}$ corresponds to the stove benefits described in Section 3. In other words, a rational household will be willing to pay exactly its total discounted savings. As before, let $\hat{\psi}_{it} = \gamma s_i$. To estimate the efficient demand curve, we use $\gamma = 39$ percent as estimated in Section 5.1 and use baseline charcoal spending as a proxy for counterfactual spending s_i. We conservatively limit the time horizon to a three-month period, as it is only within this period that our credit treatment relaxes respondents' credit constraints. We assume exponential discounting $D(t) = \delta^t$, with δ corresponding to an annualized discount factor of 0.9.[60] We define the efficient demand curve as $Q(P_E) = Pr(P_E \leq p^*)$, where P_E is the cost of adopting the energy efficient technology relative to the traditional technology. In other words, for any given price P_E, demand $Q(P_E)$ corresponds to the fraction of respondents for whom p^* is at least as large as that price.

The experimental set-up provides a straightforward estimate of the demand curve for each treatment group. Let WTP_i be the maximum WTP elicited using the BDM mechanism, and define the treatment demand curves analogously. Figure 5 displays the efficient demand curve over a three-month period for all respondents, as well as the histogram of WTP and the demand curve for the pure control group. The difference between the efficient demand curve and the pure control demand curve quantifies under-adoption.

[Figure 5]

Any reduction in the wedge between the two demand curves caused by a treatment addressing a particular constraint or bias can be interpreted as the contribution of that particular constraint or bias to the under-adoption gap.

5.3 Credit doubles WTP, while attention has no impact on savings

Access to credit increases WTP by USD 12.61, or 104 percent relative to the control group. In fact, credit alone appears to be sufficient to *fully* close the energy efficiency gap.

We precisely estimate that the attention to benefits treatment has zero impact on WTP

[59] $\bar{C}_i \geq P_E$ and the agent has costless access to credit.

[60] Figure A12 confirms that the results are robust for $\delta = 0.5$ and $\delta = 1$ (no discounting), largely because of the short time horizon.

across the entire distribution.[61,62] It appears that once respondents have access to credit, they make efficient adoption decisions in the aggregate. In the context of the model, this implies that Prediction 1 holds while Prediction 2 does not hold. Figure 6 presents these results graphically and Column (1) of Table 4 below presents the regression coefficients.[63]

[Figure 6]

The WTP of agents exhibiting risk aversion is on average USD 2 lower than the WTP of agents who do not. We find that the effect of credit is stable across people who are risk averse and people who are not, suggesting risk aversion does not drive the impact of credit. This might have been the case if, for example, the credit we provide had lower associated risks than alternative sources of credit normally available to respondents, for example due to the relatively low penalties associated with default. We discuss this more in Section 5.8.

We do not find statistically significant heterogeneity in control WTP or in the impact of any of the treatments on WTP by baseline socioeconomic characteristics such as charcoal spending, income, baseline credit constraints, household size, education, or math ability. Figure A13 shows that there is no relationship between WTP and stove benefits, whether expected or realized. This does not change with access to credit.

5.4 The psychology of credit

In addition to relaxing credit constraints, credit changes the structure of costs. It reduces the cost incurred in any single period, and it postpones when these costs are incurred. We argue that it is possible that credit works in part through psychological channels.

We test three potential psychological mechanisms: concentration bias, present bias, and inattention to future costs. We find meaningful impacts in line with theory: WTP is lower, and the impact of credit is larger, among agents exhibiting time inconsistency, and this effect is in part driven by inattention to future costs. In line with the null effect of the *attention to benefits* treatment discussed above, which operated in part through the channel of concentration bias, we do not find any evidence of concentration bias.

5.4.1 Inattention-driven myopia

Next we consider how myopia affects adoption and the impact of credit. The model predicts that the impact of credit will be smaller among agents who are encouraged to pay attention

[61] Given that our *attention to benefits* treatment was designed in part to address concentration bias, it is reassuring that we also do not find any evidence of concentration bias in costs. We discuss this more in Section 5.4 below.

[62] We rule out an effect larger than USD 1.70.

[63] Table A3 in the appendix provides a full breakdown of primary treatment effects.

to future costs. Column (2) of Table 4 presents the results. As per the model's prediction, attention to costs causes the impact of credit to decrease by USD 3.84. This is relative to an impact of credit on WTP of USD 12.62 on agents in the control group. According to these estimates, inattention contributes around 30 percent of the total impact of credit. The channel of inattention to future costs is meaningful: the large impact of credit is in part driven by inattentiveness to costs when these are incurred in the future.

To support these results, we investigate how time-inconsistency affects adoption. Theory predicts that, for time-inconsistent agents, WTP in the absence of credit will be lower (since agents are less willing to forgo utility today to increase utility in the future), but the impact of credit on WTP will be greater (since agents are now able to access future streams of utility to inform their decisions today). To investigate this, we employ our measure of time-inconsistency elicited through the effort task allocation exercise that builds on Augenblick et al. (2015) (see Section 4.5 for more detail). We define agents who choose to postpone additional tasks during their second round of decision-making as exhibiting time-inconsistency, indicated by a dummy variable.[64] Column (3) presents the results. We find that WTP is on average USD 2.51 lower, and the impact of access to credit is USD 3.12 larger, among agents exhibiting time-inconsistency.

[Table 4]

One concern is that time-inconsistency may reflect economic constraints or preferences, such as present bias, changing marginal utilities, or changing liquidity constraints, rather than inattention to future costs (see for example Dean and Sautmann (2019) and Cassidy (2019)). To investigate this channel, table A4 presents the above regression separately for respondents who exhibit time-inconsistency and those who do not. We interact the credit treatment with the ***attention to costs*** treatment. To the degree that the time-inconsistency we observe in the effort tasks is due to inattention to the future rather than true time preferences such as present bias, it is reassuring that the effects of inattention to future costs are concentrated among individuals who behave in a time-inconsistent manner as measured through the independent effort task allocation exercise. The interaction of attention and credit is large (-4.78) and statistically significant for respondents who exhibit time-inconsistency, but small (-2.35) and statistically indistinguishable from zero for respondents who do not. This suggests time-inconsistency may be driven in part by inattention to the future rather than by time preferences.

Attention to costs among the credit control group has a moderately positive impact (+2.33) on WTP, significant at the 10 percent level. These individuals may observe that

[64] Through this exercise, 57 percent of respondents were identified as exhibiting time-inconsistency.

costs will be incurred in only a single period, whereas benefits will be accrued over many periods. This may make the adoption decision look more attractive.

Math ability, as measured by a short test consisting of eight questions taken from Kenya's Certificate of Primary Education (KCPE) and Secondary Education (KCSE) standardized exams, which respondents complete during Visit 1, does not predict WTP and does not interact meaningfully with the impact of the attention to benefits treatment on WTP. This suggests that the assistance with mathematical addition is not a meaningful channel through which the attention treatment might operate.

5.4.2 Concentration Bias

We test for concentration bias (Koszegi and Szeidl 2013, Dertwinkel-Kalt et al. 2019) by comparing WTP for weekly and monthly loan deadlines. Our two credit treatments differ in the number of payments across which the total cost is dispersed. For weekly deadlines $N = 12$, while for monthly deadlines $N = 3$. Applying Prediction 3 of the model ($\frac{\partial p^*}{\partial N} > 0$), WTP would be higher with weekly deadlines if agents exhibited concentration bias.

Figure 7 separately displays the demand curves for respondents in the credit treatment group paying with monthly and weekly deadlines. Respondents paying with weekly deadlines are willing to pay on average USD 1.24 more for the stove. While this effect is consistent with theory, it is small and not statistically significant. This suggests concentration bias is not at play in a meaningful way, and respondents are largely able to correctly perceive the size of costs, regardless of how these are presented to them. Table A5 presents regression coefficients.

[Figure 7]

Fewer than 12 percent of respondents in the monthly treatment who adopted the stove chose to switch to the weekly treatment group, indicating that respondents do not appear to have a preference for commitment.

5.5 Robustness checks

This section presents results of several tests to determine whether these results are robust to a range of threats to identification. First, we confirm that systematic attrition across the three visits does not meaningfully affect our SMS or endline results. Second, we demonstrate that effects are constant across long periods of time. Third, we explore whether risk aversion and the limited liability of our loans affect take-up. We then rule out the presence of a rebound effect. Finally, we discuss the possibility that stove adoption may be welfare reducing due to hidden attributes or by displacing more profitable investments.

5.6 Attrition

One concern for identification is that selective attrition, for example by treatment status or other socio-economic characteristics, might bias results. We test for attrition and do not find meaningful variation.

We first test for attrition across the three in-person survey rounds. Of the 1,018 respondents who were enrolled during visit 1, we completed a visit 2 survey with 962 respondents (95 percent) and a visit 3 survey with 931 respondents (91 percent). Table A6 confirms that attrition is balanced across all three treatments and for most socioeconomic characteristics collected at baseline.[65]

Next, we test for attrition in the recurring SMS survey. Out of 962 respondents who completed a visit 2 survey, 838 respondents (87 percent) responded correctly[66] to at least one SMS over the course of the study. Among those 838 respondents, we received correct responses to 44 percent of the post-adoption charcoal SMSes. Table A6 tests whether baseline socioeconomic characteristics predict attrition from the SMS survey (defined as responding to fewer than the median number of SMSes) and confirms that they do not. Figure 8 displays attrition in our SMS survey among the 838 respondents in the two months after visit 2 across four dimensions: stove adoption, attention treatment assignment, credit treatment assignment, and BDM price. There does not appear to be differential attrition across any of these dimensions.

[Figure 8]

The composition of responsive participants varies across SMS cycles. Some participants responded to many SMSes while others responded to only a few. Figure A14 presents a histogram of the number of SMSes each respondent correctly responded to during the first 48 days (16 3-day SMS cycles) after visit 2. Out of 962 respondents who completed visit 2, 124 (13 percent) did not respond to any SMSes in this period. 446 respondents (46 percent) responded to at least half of all SMSes. The results are robust to running each regression at the individual level, with average spending across all SMSes on the left-hand side.

[65] Attrition is balanced across the treatment groups and BDM prices. It is slightly higher among people who are younger and people with lower charcoal expenditures, but is balanced for all other socioeconomic characteristics.

[66] An SMS qualifies as correct if it reasonably identifies the financial cost of charcoal purchased in the past 3 days. Messages that do not count as correct include messages that refer to actual quantities of charcoal (e.g. '1 KG' or '2 tins'); messages that do not include an amount (e.g. casual comments about the weather); messages that refer to credit payments or stove costs rather than charcoal spending; quantities below USD 0.10 (these are assumed to be typographical errors); or any SMS beyond a maximum of 1 SMS per day (in which case only the last correct SMS of the day qualifies).

5.7 Long-term impacts

One concern that has impacted the efficacy of prior cookstove technologies is that usage of the technology, and therefore its benefits, may decline over time, for example because the technology breaks or is poorly maintained or because users slowly learn about negative attributes and substitute into alternative technologies. The primary results in this paper only contain data for the first two months after adoption. Figure 4 in Section 5 indicates that savings are constant within this period, which is reassuring. However, existing evidence suggests that usage of modern cookstove technologies frequently declines beyond the initial two months (Pillarisetti et al. 2014; Duflo et al. 2011).

To test this, we exploit the results of a pilot RCT we launched in February 2018 with 154 low-income residents of the Kibera area in Nairobi (see Berkouwer and Dean (2018) for more details on this pilot). Respondents in that study were similar in terms of their socioeconomic status. Participants had to spend at least USD 3 per week on charcoal for a traditional charcoal cookstove to qualify for participation. The average respondent earned an income of USD 35 per week and spent USD 3.50 per week on charcoal. Furthermore, the RCT included many of the same features, including a BDM mechanism to elicit WTP and randomize stove adoption.[67] We completed a follow-up SMS survey with these respondents 18 months later, in July-August 2019.[68] The results are presented in Table 5.

[Table 5]

Eighteen months after adoption, the stove continues to cause a reduction in charcoal spending of USD 2.82, corresponding to 45 percent (59 log points) relative to the control group. These results correspond closely to the short-term results presented in Table 3 in Section 5, which estimates savings of USD 2.28 per week, a 39 percent decrease in charcoal consumption relative to the control group. This supports our assumption that savings remain constant over the long term.

This improvement on previous cookstove technologies is likely attributable to the fact that the Jikokoa is incredibly easy to use and requires no learning. It does not require any behavioral change, which is what frequently caused changes in behavior and usage over time among modern cookstoves that have been studied in the past. It is more durable than traditional stoves, and on the rare occasion that the stove breaks down, adopters have access to free repair services provided in low-income areas across Nairobi.[69]

[67] The average random price was USD 23.45 and the average WTP elicited through the BDM was USD 15, resulting in adoption of the stove by 46 out of 154 respondents (all respondents were required to pay up front).

[68] Field officers were able to contact 115 respondents (75 percent of the sample) for the 18-month endline.

[69] Respondents can call the Jikokoa service number to inquire about the location of their nearest repair

5.8 Risk aversion and default

If agents exhibit risk aversion, uncertainty can reduce technology adoption (Oliva et al. 2019). Column (1) of Table 6 demonstrates that people who are risk averse have lower WTP on average. To isolate the effect of risk preferences, this regression controls for most socioeconomic characteristics, including income and baseline savings.

The risk of adoption faced by households in the credit treatments of our study may be less than what they would face in a real-life market setting. Participants in our study do not face any financial or other penalties for payment delays, other than having to return the stove if they cannot continue the payments.[70] It is therefore possible that our particular type of credit is attractive to respondents who are risk averse, who would otherwise worry about the penalties for default with regular loans. The risk aversion task measures willingness to engage in a risky investment. If this mechanism is important, we would expect the impact of credit on WTP to be larger for individuals we identify as being risk averse. Instead, Column (2) of Table 6 indicates that there is no greater response to credit from individuals who are risk averse. This suggests this channel is not large.

Similarly, it is possible that an individual in one of the credit treatment groups strategically bids a WTP greater than their true WTP under the assumption that they can default on their loan payments without any binding repercussions if payments turn out to be unsustainable. This would cause an increase in adoption rates for respondents for whom the probability is larger that they are unable to complete their payments. This theory therefore predicts high default rates. To rule out this channel as a mechanism, we study repayment rates. While respondents are free to choose the frequency and amount of each payment, they are required to meet cumulative minimums by the relevant deadlines. Respondents who miss a deadline are reminded via repeated SMSes in the following days. Most respondents respond to these SMSes and pay within 3 days of their official deadlines.[71] As of 6 September

shop. A stove that was damaged through customer misuses (for example, being dropped from a height) does not qualify for repair. The availability this service is therefore not expected to increase misuse by inducing moral hazard.

[70] This is referred to as a *new-asset collateralized* loan in Carney et al. (2018). They find that participants in Kenya are willing to pay more for assets that are collateralized with the new asset than with an existing asset, and attribute this to an endowment effect (the agent does not yet experience an endowment effect prior to adoption of the new asset). Once agents have adopted, the agent's reference point changes and repayment increases as the endowment effect now applies to the new asset. Their predictions line up well with what we observe. A more detailed exploration of whether endowment affects adoption and repayment rates in our context is beyond the scope of this paper.

[71] If after six days a respondent has not met their minimum cumulative requirement, our field manager will call the respondent on the phone. If by day 7 the respondent has still not paid the required amount, the field manager will visit the respondent and reclaim the stove. This has happened for three respondents so far. In all three cases, the respondent faced an unexpected income or health shock and could no longer make their payments.

2019,[72] more than 80 percent of study participants who adopted the stove and are paying for it with credit reached the minimum required amount within one week of their most recent deadlines. Figure A15 shows repayment rates. 70 percent of respondents were on track at least 80 percent of the time and 82 percent of respondents were on track at least half the time. Repayment rates are generally high, and strategic default therefore likely does not drive adoption.

Default rates are high enough to warrant concern among potential lenders, and this may explain why access to credit is generally limited and costly in this context. In its annual reports, BRAC (one of the world's largest microlenders) often reports repayment rates of around 98 percent in Bangladesh, although they define repayment as having paid off the loan within one year of its initial disbursement, regardless of the frequency or size of missed payments during that one-year period—shorter-term repayment rates are closer to 90 percent. BRAC's Libera, Sierra Leone, and Uganda offices reports 86, 82, and 93 percent repayment rates, respectively. Kenya's Akiba Mashinani Trust reports repayment rates of 90 percent for livelihood loans and 76 percent for housing loans. Monitoring of repayment among our study sample is ongoing.

A respondent's average belief about the durability of the stove (measured in expected years of operation) statistically predicts WTP; however, this effect is economically small. This may be because the cookstove is well-known in Nairobi.

Diffusion may play an important role in reconciling our findings with prior research finding low adoption of profitable technologies. In his seminal work, Rogers (1962) separates the diffusion of a technology into five categories of adopters: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards. 84 percent of existing cookstove adopters reported liking *'being the first among friends to buy [a new product]'*, suggesting they are among the *innovators* or *early adopters*. In other words, the cookstove has penetrated the market for cookstoves among middle- and higher-income Kenyans who did not require credit to purchase the stove,[73] demonstrating that the quality is high and risks from adoption are low. This reduces the risk and increases the attractiveness of the stove as a signal for socioeconomic status. But reaching this majority market segment, or *'crossing the chasm'* (Moore 1991) by enabling the majority of households to adopt the technology, will require addressing the market failures that prevent them from doing so.

[72] Data collection and loan repayment is ongoing, and we expect to update these numbers.

[73] 69 percent of existing customers reported buying the stove in cash, without access to credit.

6 Welfare implications

In this section we generate an estimate of aggregate welfare effects. We first argue that WTP, which is often used to infer welfare gains, cannot be interpreted in this way in this context because of the large credit constraints. Instead, we enumerate and compute aggregate private and social benefits for the most plausible channels. The most significant benefits from two years of ownership[74] consist of avoided environmental damages in terms of greenhouse gas emissions (USD 207), financial savings (USD 214), time savings (USD 231), and improvements in health outcomes. We exclude health benefits from the aggregate monetary equivalent calculations because these are difficult to quantify for reasons discussed in Section 6.3. Table 7 provides an overview of the impact of adoption on non-financial outcomes.

[Table 7]

We define ***'private benefits'*** to be the discounted sum of financial savings and time savings. This equals USD 444. Finally, we define ***'total benefits'*** to be the total discounted sum of private benefits and reductions in environmental externalities. The sum of these equals USD 651. Both of these sums vastly outweighs the retail cost of USD 40, suggesting a significant welfare gain to our participants. We rule out two primary concerns commonly associated with identifying welfare improvements in this context: the presence of welfare-reducing attributes and energy rebound effects.

Finally, we perform a back-of-the-envelope calculation to quantify the Marginal Value of Public Funds (MVPF), or the total welfare gains in USD generated from every 1 USD of government spending if the government were to implement a subsidy program for the efficient stoves. We estimate that, for a policymaker who is solely interested in poverty reduction and therefore only cares about private benefits, the MVPF is USD 13. When factoring in the avoided environmental damages, the MVPF increases to USD 19.

6.1 The policy interpretation of *willingness-to-pay*

Policy-makers and researchers often infer welfare gains of a product or intervention from beneficiary willingness-to-pay (WTP) in order to design optimal policy. For example, in the context of environmental and health economics, WTP is often used to value environmental attributes or individual health outcomes. In public finance, Hendren and Sprung-Keyser

[74] All welfare calculations are discounted at $\delta = 0.9$ annualized.

(2019) define the MVPF as the ratio of marginal benefits to the net marginal cost to the government, with benefits "measured as their willingness to pay."[75]

However, market frictions may create a wedge between WTP and ***ability-to-pay*** (ATP), which is what is generally observed or elicited when subjects face their usual constraints, either in the real world or during field experiments. Given that ATP is constrained WTP, revealed preference methods may underestimate realized welfare gains. This has meaningful implications for the validity of revealed preference and other methodologies in low-income settings: in the context of large credit constraints, the welfare implications of stove adoption cannot be inferred from WTP.[76]

6.2 Environmental externalities

Under-adoption of energy efficient charcoal stoves causes significant negative externalities that contribute to global climate change, as documented in section 2. Respondents in our sample report spending on average USD 5.59 on charcoal each week, or USD 290.71 per year. Throughout this project the price of charcoal in the study neighborhoods in Nairobi was around USD 0.30 per 1 KG of charcoal.[77] Each respondent then consumes an average of 969 KG per year. The 39 percent reduction caused by the adoption of each energy efficient stove thus saves 758 KG over the course of two years of ownership.

The Food and Agriculture Organization of the United Nations (2017) estimates that each KG of charcoal burned by a household in Kenya emits between 7.2-9.0 KG of CO_2***e***. The EPA's estimate for the 2020 social cost of a metric ton of CO_2 is USD 42 (U.S. Environmental Protection Agency 2016).[78] Adoption of a stove then corresponds to on average a reduction of 5.5 metric tons of CO_2***e***, valued at USD 207 over the course of two years.

6.3 Impacts on health and WTP for health

Column (2) of Table 7 suggests stove adoption causes significant improvements in self-reported health.[79] Adoption of the stove causes a 0.56 standard deviation improvement

[75] We discuss the MVPF further in Section 6.7.

[76] For example, Banerjee (1997) discusses how credit constraints can increase the gap between WTP and ATP and exacerbate red tape in the context of government bureaucracy.

[77] Field officers conducted short surveys with local charcoal sellers throughout the course of this study to collect pricing data.

[78] The EPA presents a wide range of plausible estimates of the social cost of carbon, between USD 11 to USD 220, arising from uncertainty in climate outcomes, varying discount rates, and temporally heterogeneous damages.

[79] The health index consists of self-reported health and respiratory symptoms for the primary cookstove user and any children (if applicable). The index is standardized for the control group to have a mean of 0 and a standard deviation of 1.

in health. While health is self-reported and therefore subject to experimenter demand or Hawthorne effects, the fact that it is strongly correlated with independently measured charcoal usage (in KG) in Column (4) is reassuring. Respondents who use more charcoal on average report more respiratory symptoms.

These health benefits and high take-up rates (after relaxing credit constraints) stand in contrast to a large literature that generally finds that demand for improved cookstoves is low and inelastic to messaging around the potential health benefits. (Pattanayak et al. 2019; Mobarak et al. 2012; Hanna et al. 2016; Levine et al. 2018; Burwen and Levine 2012). One way to reconcile these results is to assess whether the potential health benefits affected our respondents' take-up decisions. Column (1) of Table 7 reports that households with higher beliefs about the harms of the traditional stove and the potential health benefits of the improved cookstove on average do not subsequently state a higher WTP during the BDM elicitation,[80] but households with higher beliefs about the potential financial savings of the stove do. This rationalizes prior results in the literature: even if stoves have the potential to meaningfully improve health, households may not be able to pay more for such a stove due to financial constraints, prioritizing investments in technologies that generate financial returns.

We consider whether health benefits are moderated by continued use of the traditional stove despite adoption of the improved cookstove. Of the 511 respondents who still possessed a Jikokoa at endline,[81] 18 percent continue to use their traditional stove at least once per month.[82] Columns (3) and (4) test whether the impact of adoption of the energy efficient stove on health differs by whether the respondent continues to use their old stove. We find suggestive evidence that this is the case, but this effect is moderated when controlling for the quantity of charcoal (in KG) a household uses each month, which itself strongly predicts both health and continued old stove usage. Additionally, continued use of the old stove and quantity of charcoal used were not randomly assigned. We therefore urge caution in interpreting these results.

We refrain from quantifying health benefits. While reduced smoke emissions and improved self-reported health outcomes suggest health benefits may be very large, there is substantial uncertainty in the tangible health benefits from reduced indoor air pollution,

[80] Given that the health index is normalized to a mean of 0 and a standard deviation of 1 in the control group, we can bound the impact of a standard deviation increase in health beliefs to less than a USD 0.12 increase in WTP.

[81] 16 people (3 percent of adopters) purchased the stove during the midline survey but no longer had it during the endline survey. Reasons include: they gave it to a friend or family member; they are keeping it in their rural home; they had to return it because they defaulted on their payments; it was lost in a fire.

[82] Many report doing so because they were afraid to switch to the energy efficient stove before fully paying it off, suggesting this number may drop in the long term.

medical costs in the local context, and estimates of value of statistical life and disability-adjusted life years. This makes it impossible to meaningfully convert these improvements to a monetary equivalent. We therefore exclude health benefits from our aggregate calculations below, noting only that our calculated benefits are likely to be a lower bound on the true total.

6.4 Other non-financial attributes

In many ways, the energy efficient stove is similar to the traditional stove. Two-thirds of respondents that adopted the energy efficient stove said they did not change which foods they cook, and more than 71 percent said they cook the same quantity of food as before. Nevertheless, respondents reported additional improvements through other channels. 61 percent of respondents said that food cooked with the energy efficient stove tasted slightly or a lot better, and fewer than 1 percent said the food tasted worse.

The energy efficient stove also generates significant time savings. Column (5) of Table 7 reports that the mean respondent reduces their time spent cooking by around one hour per day.[83] Figure A17 displays the full distribution of daily cookstove usage for households in different treatment groups with high rates of compliance. We perform a back-of-the-envelope calculation of the monetary equivalent of these time savings. We use median earnings of USD 3 per day and we assume daily earnings scale linearly with hours worked, starting at an 8-hour work day. We find that time savings correspond to an additional savings of USD 0.35 per day, which represents an additional 107 percent of median financial savings from the efficient stove, almost doubling the total benefits of the stove. Two years of stove ownership would thus contribute an additional USD 256 in discounted time savings.

More than two-thirds of respondents report that the space heating generated by the stove helps keep their living space warm during the colder winter months. The endline survey was conducted in the months of June and July, which are historically the coldest months in the year—temperatures can drop to the single digits (°C)—so the reported heating benefits were likely large relative to the annual average. Despite these heating benefits, the majority of respondents never burn charcoal *purely* with the goal of heating the living space. Among the respondents that do, the majority do this for an hour or less each day. Heating is thus generally a positive externality from cooking rather than a goal in and of itself. While this is worth recognizing, we refrain from estimating a welfare gain from the heating externality in financial terms.

Finally, to assess the potential for learning externalities, we evaluate whether households

[83] This reduction in cooking time is likely driven by a reduction in the time spent preparing and lighting the charcoal. This process is time-consuming for traditional cookstoves.

in close geographic or social proximity to respondents in our sample currently have the Jikokoa. Column (6) documents that we do not find any evidence of network effects in this context, defined as an increased number of adoptions by neighbors, friends, or family of the respondent in the month after adoption. This serves as further evidence against the idea that the binding constraint is information or perceptions of stove quality.

6.5 Ruling out welfare-reducing attributes

If stove adoption causes unpredictable negative impacts, it is possible that providing access to credit may be welfare-reducing. We can rule this out for several reasons. First, Appendix Figure A16 compares WTP as measured during the BDM mechanism with stated WTP elicited during the endline survey. We find that the relationship between WTP across these two periods is nearly identical for respondents who adopted the stove and those who did not. It is therefore unlikely that there is substantial learning of any welfare-reducing hidden attributes post adoption. Second, at the endline, 99 percent of stove adopters say they recommend the stove to friends and family members, and fewer than 1 percent had ever considered selling it, suggesting there are no hidden non-financial stove attributes that are welfare-reducing.[84] A final concern might be that, by investing in the stove, a household may forgo an alternative investment with a higher internal rate of return. Table 3 discusses existing estimates from the literature of alternative investments that are likely to be available to this population, including investments in healthcare and enterprises. We find very limited evidence that more profitable alternative investments exist.

6.6 Ruling out a rebound effect

Originally documented in Jevons (1866), the rebound effect refers to a phenomenon in technological progress whereby improvements in production efficiency designed to reduce usage of an input are partly offset by increased usage. At an extreme, the offset might be so large that the efficiency gain *increases* usage of the input - this is often referred to as the Jevons paradox. A large literature in energy economics documents the existence of a rebound effect in energy efficiency adoption (Borenstein 2015; Gillingham et al. 2015; Chan and Gillingham 2015), where individuals increase usage of an appliance after adoption of an energy efficient version of that appliance. This is often due to either an income effect (individuals use savings

[84] This question is subjective and a concern might be that respondents felt experimenter demand effect, or an expectation to report positive experiences after having benefited from the subsidy offered by the study team. To limit such a channel, field officers repeatedly informed the respondent that they were part of a university research team, that they were working entirely independently from the cookstove company, and that their responses would remain anonymous.

generated from the investment to use the appliance more) or a substitution effect (usage of the appliance is now relatively cheaper). The presence of a rebound effect would complicate the interpretation of the causal effect we identify. Increased usage can reduce the net savings generated from the adoption of the energy efficient technology, but it may also increase utility derived from the technology, which must be quantified in order to understand the welfare implications.

We can rule out the presence of a rebound effect in our context for two reasons. First, more than 71 percent of respondents who adopted the energy efficient stove report that the amount of food that they cook has stayed the same since they adopted the stove, with 23 percent stating that this amount has "increased slightly."[85] Qualitatively this suggests that the rebound effect is unlikely to be large. This may be attributable to the fact that time spent cooking is generally an inelastic good. A regression of log of time spent cooking on log of income yields a coefficient that is not statistically significant from zero and rules out an elasticity greater than 0.14.

Second, the presence of a rebound effect would generate a wedge between between engineering estimates of energy efficiency and realized energy efficiency gains from individual adoption. The stove manufacturers in conjunction with the Berkeley Air Monitoring Group and the University of Washington previously estimated that the reduction in charcoal required to reach and maintain equivalent temperatures when using the Jikokoa stove is 43—45 percent of a traditional Kenyan stove. Our point estimate, which factors in human behavior, is a 39 percent reduction with a 95 percent confidence interval of (30, 48). We therefore cannot rule out that the engineering estimates line up with realized savings.

Finally, a rebound effect would cause an increase in the time spent cooking, whereas we find a decrease of 56 minutes per day. This suggests that any rebound effect is likely to be small.

6.7 Marginal value of public funds (MVPF)

In our study setting, credit constraints are large, there is relatively low variation in charcoal usage across respondents,[86] and the cost of adoption is less than the reduction in environmental externalities for the vast majority of respondents. For this reason, a subsidy would be significantly more effective than a tax in this setting. We perform a back-of-the-envelope[87]

[85] This conservatively represents an upper bound on the rebound effect for time spent cooking, since time spent cooking does not scale linearly with the quantity of food cooked.

[86] 87 percent of respondents purchase between USD 3–7 of charcoal each week.

[87] In particular, we assume homogeneity in costs and benefits across respondents. This is a realistic assumption for the cost of production. It is not necessarily a realistic assumption for the benefits, since usage is heterogeneous, but the result will still be a reasonable approximation of the true MVPF.

calculation to evaluate the costs and benefits of a government subsidy for energy efficient charcoal cookstoves.

In the context of public finance, Hendren and Sprung-Keyser (2019) define the Marginal Value of Public Funds (MVPF) as the ratio of marginal benefits to the net marginal cost to the government. As discussed above, the average total private benefits from two years of ownership equal USD 444. The average total benefits, which consist of private benefits and avoided environmental damages, equal USD 651. We use the demand curve for the credit control group elicited through the BDM mechanism to account for inframarginal participation.[88] In particular, 99 percent of adopters under a USD 30 subsidy are inframarginal participants. Finally, we use a marginal cost of public funds (MCF) of 1.13 as estimated in Auriol and Warlters (2005).

These parameters yield a MVPF of USD 13 when considering private benefits alone. Subsidies for the energy efficient stove are a highly effective policy tool even for policy makers who are solely concerned with poverty reduction. When also factoring in reductions in negative externalities such as the contribution of charcoal use to climate change, the MVPF rises to USD 19. Table 7 presents additional estimates of the MVPF under various assumptions of the social cost of carbon, the value of time benefits, and the rate of inframarginal adoption.

7 Policy implications: Pigovian taxation of externalities under credit constraints

In this section we explore potential policy solutions that can reduce environmental externalities in the context of large credit constraints. Section 6 shows that the potential for this is significant: each cookstove generates on average USD 207 worth of greenhouse gas emissions reductions.

Low-income country governments are increasingly adopting carbon taxes as a tool to reduce emissions of greenhouse gases and local environmental pollutants. South Africa, Chile, and Mexico have all enacted a carbon tax since 2014, each covering at least 40 percent of greenhouse gas emissions (World Bank Group 2018). A common concern is that costs will likely be passed through to increase electricity and gasoline prices and disproportionately burden the poor. This has motivated a growing equity-efficiency debate. However, given large credit constraints in these contexts, we argue that, in addition to any equity concerns, these tools may not even achieve the intended abatement.

[88] Some subsidies may be paid to participants who would have purchased the stove even without the subsidy. See Boomhower and Davis (2014) for a more formal treatment of inframarginal participation in energy subsidy programs.

Market failures can constrain policymakers to adopting second-best policies that achieve lower welfare (Fullerton and Wolverton 2005; Knittel and Sandler 2018). An extensive literature studies second-best regulation of environmental externalities in the presence of market failures and other constraints.[89] Allcott et al. (2015) investigate how heterogeneous market failures such as credit constraints impact the targeting of energy efficiency subsidies.

The energy efficient technology in this paper is profitable and salient but credit constraints prohibit adoption for most agents. The market failures that exacerbate credit constraints could be caused by, for example, information asymmetry (a lender cannot perfectly identify likely defaulters) or moral hazard (agents adopt riskier technologies the cost of default is low). We are agnostic to the source of the market failures but we assume that the policymaker is unable to improve credit markets directly. The policymaker therefore must address two separate market failures, negative environmental externalities and credit market failures, using two policy instruments: a tax t on the energy input and a subsidy s on the energy efficient technology.[90] However, there is little evidence on how these might interact—in most high-income countries, the cost of the energy efficient technology P_E is generally well below most people's credit constraints $\bar{C}$. In particular: how do credit constraints affect optimal regulation of negative environmental externalities?

We begin by evaluating the efficient case without credit constraints. Consider an agent using an energy-intensive durable and a policymaker looking to curb negative environmental externalities generated through usage of the energy input, where the relationship between the energy input (charcoal) and the emitting good (carbon) is fixed. Each agent i has a fixed and perfectly inelastic utilization m_i of the durable and quasi-linear utility. Inelastic utilization is a reasonable assumption in the context of many energy consuming durables, including for example cookstoves, refrigerators, and lightbulbs. Empirically, households rarely change usage of these appliances in response to electricity cost changes. Cookstove utilization (time) in our sample is almost entirely inelastic with respect to both stove adoption and income.[91] They decide[92] whether to adopt an inefficient (I) version of the energy consuming durable, or an efficient version (E) with premium P_E.[93] Let ϵ denote the efficiency gain in producing

[89] For example, market power (Baumol 1972; Fowlie et al. 2016), principal-agent misalignment (Blonz 2019; Myers 2015; Davis 2012), technological or administrative feasibility (Sallee 2019), and political constraints (Meckling et al. 2017; Jenkins 2014; Goulder and Parry 2008; Fullerton 1997).

[90] In practice, policymakers have implemented a wide range of energy efficiency policies, including for example efficiency standards or bans on inefficient technologies. We argue that these are generally infeasible in the context we study for institutional reasons, and are often also more regressive (e.g. Levinson (2019)).

[91] See Section 6.6 for a discussion of the rebound effect.

[92] We consider a single decision point, but the model could be extended to consider dynamic decisions in order to account for option value in the case of uncertainty about technology costs or fuel prices.

[93] We normalize $P_I = 0$ so that P_E is cost of switching to E. In our setting, $P_E = 40$ while $P_I = 3$ for the median respondent. We assume perfectly elastic supply of stoves at P_E.

a unit of utilization using the energy efficient technology relative to the inefficient technology (in our estimates, $\epsilon = 39\%$). The energy input has a fixed, exogenous price p per unit.[94] Conditional on adopting technology j, the agent's utility is fixed, as follows:

$$U_I(m) = u(m) - m(p+t)$$
$$U_E(m) = u(m) - (1-\epsilon)m(p+t) - (P_E - s)$$

The agent thus will adopt the energy efficient technology E if the fuel savings exceed the cost of adoption. The total energy savings, represented by $m(p+t)$, are analogous $\sum_{t=1}^{T} \psi_t$ in Section 3.

$$P_E - s < \epsilon m(p+t)$$

Note that the agent ignores the externality ϕ (Any one individual's contribution to climate change has negligible impacts on their own welfare). The social planner, on the other hand, considers the externality ϕ. Assuming full revenue recycling of t and s, the planner's social welfare function is given by the sum of welfare across individuals who choose to adopt ($i \in E$) and individuals who do not:

$$W(t,s) = \sum_{i \in E} [u(m_i) - em_i(p+\phi) - P_E] + \sum_{i \notin E} [u(m_i) - m_i(p+\phi)]$$

In a first-best world, the efficient solution for the social planner is to set a Pigovian tax t on the emitting good equivalent to the negative environmental externality ϕ (Pigou 1920): $t^* = \phi$. Any technology subsidy would be distortionary: $s^* = 0$.

We argue that under credit constraints, and with inelastic demand for the energy consuming technology, a positive technology subsidy ($0 < s$) and a positive tax that is less than the Pigovian level ($0 < t < \phi$) together will address environmental externalities more efficiently than Pigovian taxation alone.

The intuition for this is straightforward. Consider the impact of a tax $t = \phi$. An agent facing binding credit constraints cannot respond optimally to the incentives generated by the tax. However, by lowering the cost of the energy efficient technology in any given period, a subsidy acts like credit and ***can*** induce this agent to adopt—a subsidy effectively targets credit constrained agents. In particular:

> (1) Suppose $t > \phi$. For any agent who is marginal to this tax, relative to a tax $t = \phi$, the marginal cost of adoption must exceed the marginal

[94] Price p fluctuates over time and is uncertain over future periods. This model can incorporate uncertainty and accommodate, for example, risk aversion or option value in a dynamic setting.

environmental damages avoided. Their adoption is thus welfare-reducing. Thus, $t^* \leq \phi$.

(2) Suppose $s \leq 0$. Given that $t^* \leq \phi$ and that binding credit constraints must necessarily reduce adoption, there will be agents for whom the social benefits of adoption exceed the costs but who are unable to adopt due to credit constraints. The inefficiency from infra-marginal participation is second-order relative to the efficiency gain from increasing adoption among agents with high utilization but binding credit constraints. Thus, there exists $\kappa > 0$ such that $W(t, s = \kappa) > W(t, s = 0)$. Thus, $s^* > 0$.

(3) Given $s^* > 0$, a tax $t = \phi$ will cause over-adoption. Hence, $t^* < \phi$.

(4) Suppose $t = 0$. A subsidy $s^* > 0$ will not target the externality ϕ and may therefore induce adoption among agents with lower utilization. This will not provide the environmental gains that would be generated if high-utilization agents adopted the stove. A larger subsidy will therefore induce adoption among agents who are not credit constrained but for whom the cost of adoption exceeds total social benefits, reducing welfare. Thus, $t^* > 0$.

Thus, the optimal policy is a combination of a positive subsidy $0 < s^*$, and a positive tax that is less than the damages, such that $0 < t^* < \phi$. The relative size of t and s will depend on the size of the environmental externality ϕ and the extent to which the credit market failure affects adoption.

In addition, the relative sizes of s^*, t^* will depend on the correlation between usage m_i and the credit constraint $\bar{C}_i$. If agents with tighter credit constraints are more likely to have ***higher*** utilization,[95] then the subsidy will still target agents with higher utilization, and the distortion will be lower. On the other hand, if agents with tighter credit constraints have ***lower*** utilization,[96] then the subsidy will target agents with ***lower*** utilization, creating a larger distortion. The degree to which a subsidy is more efficient than a tax will therefore depend on the degree to which the subsidy induces noisy targeting. This is determined by the correlation between m_i and $\bar{C}_i$.

More broadly, we argue that environmental policy must be adapted to local contexts. Little is known about how Pigovian taxation and other key theoretical results from environmental economics affect welfare empirically in low-income contexts. More research is needed

[95] A low-income family may have lower credit limits and also eat more meals at home rather than in restaurants, or have less insulation in the home thus requiring more heating, and therefore have higher m.

[96] For example, a low-income family consumes less and therefore uses its appliances less.

to understand the particular market failures at play and to develop environmental policies that are optimal in the local context.

8 Conclusion

In an efficient market, a rational and time-consistent agent will adopt a technology as long as its marginal benefit exceeds its marginal cost. We observe a setting where marginal benefits greatly exceed the marginal cost of adoption for $>$ 99 percent of agents. Is this under-adoption caused by agents making errors in their adoption decisions? Or, do they face external constraints that prevent them from adopting?

We study this question in the context of an energy efficient household technology in Nairobi, Kenya. We estimate that the technology reduces household charcoal spending by 39 percent, saving the average household USD 119 per year, which corresponds to on average one month of household income. At a retail price of USD 40, this corresponds to an IRR of 300 percent per year. We identify significant under-adoption: despite these large benefits, participants in our control group are only willing to pay USD 12 for the stove.

Access to credit more than doubles WTP for the stove. Qualitative evidence suggests that the gains in well-being from stove savings are significant. More than 60 percent of respondents report using the savings for critical household expenditures such as food items and child school fees. This means governments looking to reduce poverty by increasing household adoption of profitable technologies may find that addressing market failures in the credit sector can provide tangible opportunities for welfare gains for poor households.

We find evidence that credit operates in part through a psychological channel. In addition to relaxing credit constraints, credit changes the cost structure, from a single large payment today to multiple smaller payments in the future, and this affects how an agent perceives the cost of an investment. We find that around one-third of the large effect of access to credit on WTP is driven by inattention to future costs. Encouraging an individual to pay attention to these future costs reduces the impact of access to credit on adoption, suggesting people may not fully attend to costs when they are in the future. This effect is driven almost entirely by people who exhibit time-inconsistent preferences as measured by an independent effort task allocation exercise. Time-inconsistent agents have on average lower WTP in the absence of credit, and the impact of credit on WTP is larger among these agents, but inducing attention to costs reduces these agents' responsiveness to credit. This suggests that existing measures of time-inconsistency at least in part reflect inattention to the future rather than agent preferences.

On the other hand, we do not find that attention to benefits has any significant direct impact on WTP. This is in contrast to many papers in the energy literature as well as the development literature that would predict significant behavioral biases, particularly for energy efficiency adoption decisions among this low-income population. Individuals already pay attention to the costs and benefits reasonably accurately and attentively, and are making decisions accordingly. This departure from previous literature may be due to the fact that the decision at play has high financial consequences: the median respondent saves one month of income. There is modest evidence in the literature that when stakes are higher, cognitive performance among the poor improves (Fehr et al. 2019). It may also be that energy expenditures are easier to track when inputs and outputs are perfectly correlated—charcoal usage is relatively easy to track when its sole usage is for charcoal cookstoves. This is analogous to gasoline usage to power a vehicle, and may explain why our findings align with prior evidence showing households correctly evaluate costs against future gas prices when deciding whether to purchase a more energy efficient vehicle.

Finally, we document the policy implications of large credit constraints for the regulation of environmental externalities in low-income settings. In the absence of market failures, a Pigovian tax equal to the cost of the negative externality achieves efficiency. A credit constrained agent, however, would not be able to respond optimally to a Pigovian tax. We argue that under reasonable conditions relating to the size of the welfare distortion generated by credit constraints and the environmental externality, as well as their correlation, subsidies can achieve higher welfare gains than taxes alone. Credit constraints are widespread across many low and middle-income countries, and we argue that this has important implications for environmental policy going forward. We estimate that providing a USD 30 subsidy for the energy efficient stove has a Marginal Value of Public Funds (MVPF) of USD 13 when factoring in the private benefits alone. This is a highly effective poverty alleviation program even for policy makers who are not concerned with environmental externalities. When avoided environmental damages are included, the MVPF rises to USD 19.

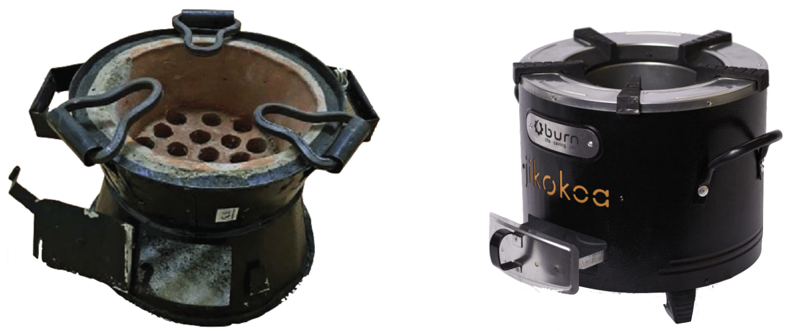
The large impact of credit constraints combined with high repayment rates invites the question of why profit-maximizing companies do not offer credit. While a detailed accounting of specific factors driving failures in the credit market in Kenya is beyond the scope of this paper, informal conversations with decision-makers in this sector yield some plausible explanations. Of primary importance are fears of over-extension if technology firms essentially expand into the credit sector. The primary strength of energy efficient technology companies is in developing and marketing these technologies—extending into activities beyond this scope may jeopardize the quality of those products. Second, a large gap exists between the formal and informal sectors. A manufacturing company interested in offering credit to its customers may be more likely to partner with an existing formal banking institution, but the population studied in this paper are almost entirely served by informal financial providers. Prior collaborations between banks and technology companies in Nairobi have primarily targeted households with higher socioeconomic status, and have thus been limited in scope.

Low and middle-income countries are expected to propel future energy demand. Energy efficiency is often presented as an example of a technology that can benefit households financially while also reducing the strain on energy systems, yet adoption remains low. We illustrate that policy makers cannot rely on households to prevent this strain by adopting energy efficient technologies. Households in our study would like to adopt more energy efficient versions of their primary energy durable but are unable to do so due to credit constraints. A reduction in the distortion created by inefficient credit markets would allow policy-makers to abate growing energy demand, and allow households to benefit from technologies with high returns.

Figures

Background: Charcoal use and spending in Kenya

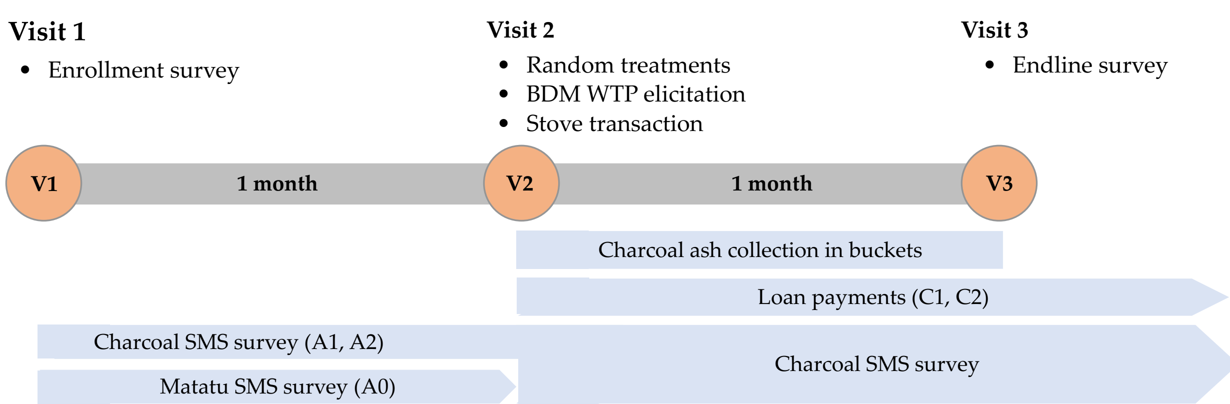
Figure 1: Traditional *jiko* ('stove') and energy efficient stove



On the left is the traditional *jiko*. On the right is the energy efficient stove. The two stoves use the same type of charcoal and the same process for cooking food, hence the energy efficient stove requires essentially no learning to adopt. After usage, the user disposes of the ash using the tray at the bottom. The central chamber of the energy efficient stove is constructed using insulating materials, creating a higher charcoal-to-heat conversion rate. Engineers ex-ante predict that the energy efficient stove uses only half the charcoal to reach and maintain the same cooking temperatures as the traditional *jiko*.

Experimental Design

Figure 2: Experimental Timeline



Timeline of the four main study components: 1) Three in-person visits, timed one month after each other; 2) A recurring SMS survey about charcoal spending (a control group received placebo SMSes about matatu (buses) for the first month); 3) Ash collection in buckets to measure charcoal consumption; 4) Loan payments (for respondents who purchased the stove and used a loan to do so).

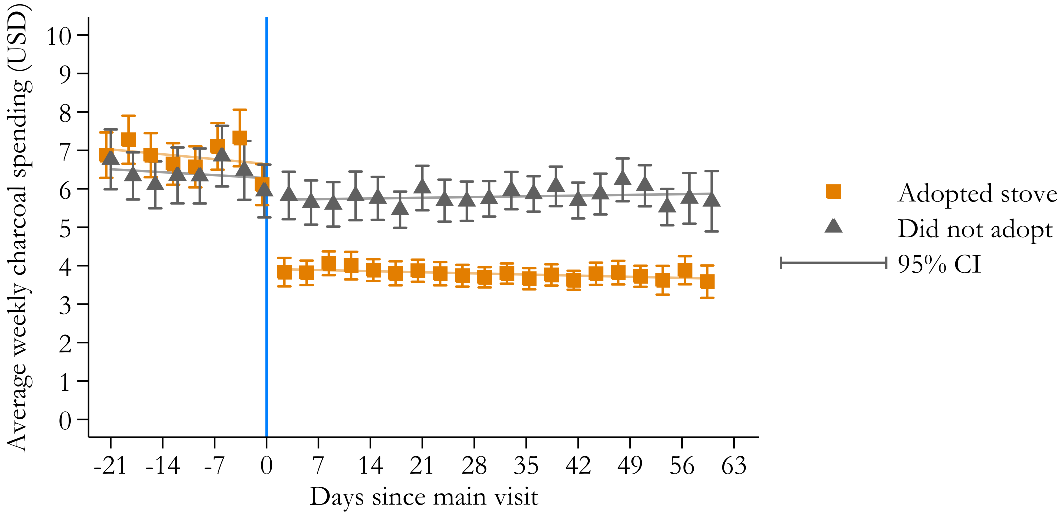
Figure 3: Experimental Treatment Arms

		Credit Control	**Credit Treatment**	
			Weekly Deadlines	Monthly Deadlines
Attention Control		96	98	98
Attention Treatment	Energy Savings	96	97	96
	Energy Savings – Costs	145	146	146

We enroll 1,018 respondents and randomly assign them to one of three credit treatments and one of three attention treatments. Respondents in the credit control group must pay for the stove during visit 2 and receive the stove that day. Respondents in the credit treatment group still receive the stove during visit 2 but pay for it over 3 months. Respondents in the attention control group receive basic information about the stove. Respondents in the attention treatment group are prompted to report charcoal spending every three days in the month before WTP is elicited, to forecast 12 months of savings and spend time thinking about how they could use the savings. Respondents in the treatment to costs group also think through costs associated with adoption. Treatment assignment is stratified by baseline charcoal spending.

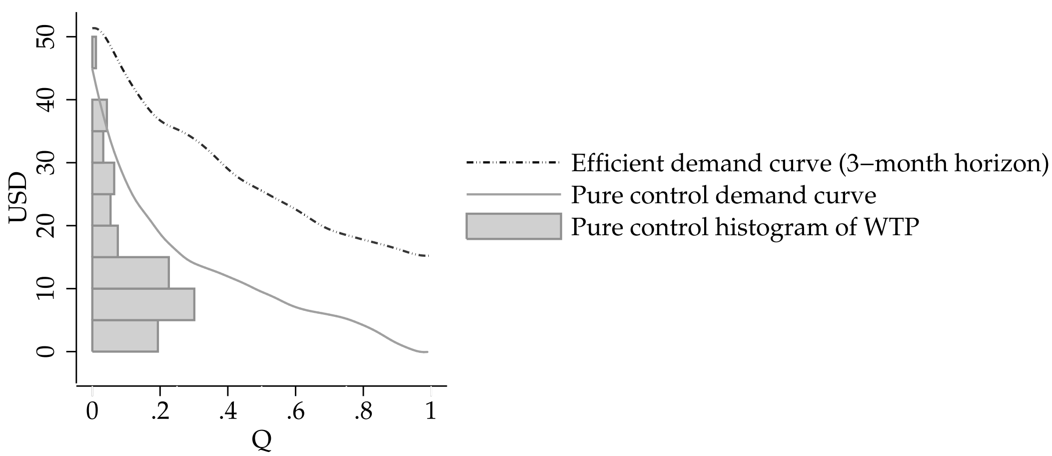
Results

Figure 4: Energy efficient stoves reduce energy spending



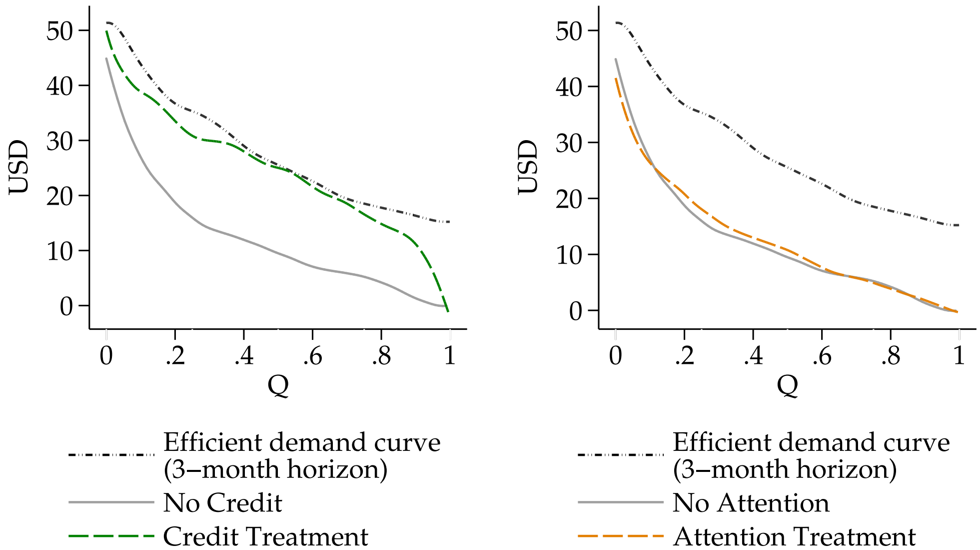
Weekly charcoal spending by adopters and non-adopters of the energy efficient stove before and after visit 2. Weekly charcoal spending is elicited through a recurring 3-day SMS survey. Adoption of the stove causes charcoal expenditures to drop by USD 2.20 per week (40 percent relative to the control group). The causal estimates presented in Figure A10 are similar.

Figure 5: Under-adoption of the energy efficient technology



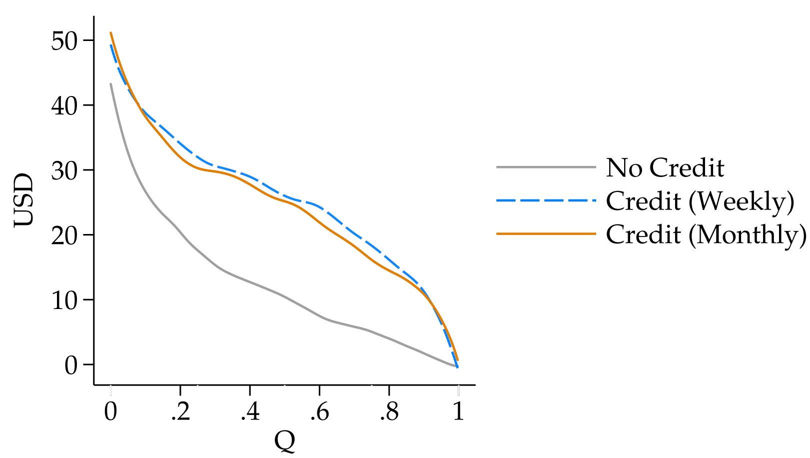
The dotted line represents the efficient demand curve for all agents, if agents were willing to pay precisely their savings over a 3-month period. The smooth line and the histogram represent demand elicited through the BDM mechanism for the control group. The gap between the two curves can be interpreted as under-adoption of the energy efficient technology.

Figure 6: Impacts of experimental treatments on WTP



Cumulative distribution of WTP for the control and treatment groups for both experimental treatments. The credit WTP graph includes only the attention control group and vice versa. Access to credit increases WTP by USD 13 (104 percent relative to control). Attention to benefits does not affect WTP. The efficient demand curve assumes annualized $\delta = 0.9$. Figure A12 presents robustness checks for annual discount factors $\delta = 0.5$ and $\delta = 1$.

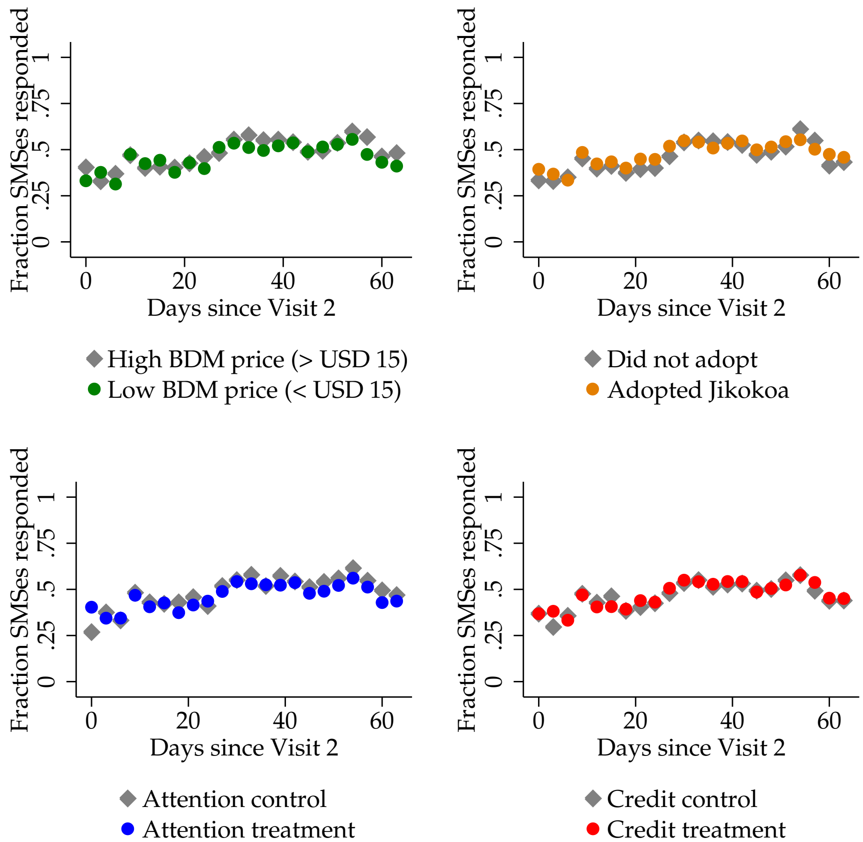
Figure 7: Test of concentration bias



An agent exhibiting concentration bias would prefer payment plans where costs are dispersed across a larger number of smaller payments rather than concentrated in a smaller number of larger payments. We test for this by randomly assigning respondents to pay by either weekly or monthly deadlines. WTP is presented for the two credit treatments separately. Credit increases WTP by 13 USD on average but the framing of deadlines (weekly or monthly) does not affect adoption, suggesting concentration bias is not at play.

Robustness Checks

Figure 8: Attrition of SMSes by adoption and treatment status



We test for attrition in SMS responses by Jikokoa adoption and treatment status for all three treatments (credit, attention, and subsidy). We do not observe meaningful differences in response rate by treatment group or by whether the respondent adopted the stove.

Tables

Experimental Design

Table 1: Summary Statistics

	Mean	SD	25^{th}	50^{th}	75^{th}
Household size	4.73	2.08	3	4	6
Age	37.24	11.83	29	35	44
Female respondent	0.95	0.21	1	1	1
Completed primary education	0.70	0.46	0	1	1
Completed secondary education	0.06	0.24	0	0	0
Household income (USD/week)	47.12	34.56	21	35	60
Energy spending (USD/week)	8.54	3.58	6	8	10
Charcoal spending (USD/week)	5.59	2.60	4	5	7
Savings (USD)	74.59	129.07	1	30	82
Current cookstove price (USD)	3.40	1.34	3	3	4

Summary statistics of key socioeconomic characteristics for all 1,018 study participants. 'Savings' includes savings in bank account, mobile money account, or informal group savings.

Results

Table 2: Causal impact of stove adoption on weekly charcoal spending

	First Stage	IV Estimate		
	(1) Bought Stove	(2) USD	(3) IHS(USD)	(4) IHS(KG)
BDM Price (USD)	-0.029***			
	(0.001)			
WTP (USD)	0.025***	-0.003	-0.001	0.004
	(0.001)	(0.011)	(0.003)	(0.003)
Bought Cookstove (=1)		-2.279***	-0.496***	-0.490***
		(0.296)	(0.072)	(0.083)
Observations	920	7923	7923	803
Control Mean	0.400	4.960	2.154	1.546
Socioeconomic controls	Yes	Yes	Yes	Yes
Data Source	Midline	SMSes	SMSes	Buckets

Results from an instrumental variables regression that uses the (randomly assigned) BDM price as an instrument for stove adoption to estimate the causal impact of adoption on weekly charcoal expenditures. Column (2) uses weekly charcoal expenditures in USD as the outcome variable. Column (3) uses the inverse hyperbolic sine (IHS) conversion of the USD amount. A 0.496 IHS reduction corresponds to a 39 percent reduction relative to the control group. Column (4) uses the IHS of the weight of the charcoal bucket one month after stove adoption as the outcome variable. Table A2 confirms that these results hold for additional specifications. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. In regressions using SMS data, errors are clustered by respondent. SE in parentheses. $^{*} \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

Table 3: Empirical rate of return estimates from selected literature

Authors	Year	Country	Annualized IRR
Berkouwer and Dean	2019	Kenya	296%
Energy Efficiency			
Allcott and Greenstone	2017	USA	-4%
Fowlie, Greenstone, Wolfram	2018	USA	-10%–0%
Davis, Martinez, Taboada	2018	Mexico	*less than* -8%
Firms			
Bigsten, Isaksson, Soderbom, et al.	2000	Africa[1]	10–35%
McKenzie and Woodruff	2006	Mexico	36–180%
McKenzie and Woodruff	2008	Mexico	240–396%
De Mel, McKenzie, Woodruff	2008	Sri Lanka	55–63%
Kremer, Lee, Robinson	2013	Kenya	113%
Fafchamps, McKenzie, Quinn, Woodruff	2014	Ghana	180%
Banerjee and Duflo	2014	India	105%
Blattman, Fiala, Martinez	2014	Uganda	30–50%
Blattman, Green, Jamison, et al.	2016	Uganda	8–24%
Agriculture			
Udry and Anagol	2006	Ghana	30–50%
Duflo, Kremer, Robinson	2008	Kenya	52–85%
Education			
Bigsten, Isaksson, Soderbom, et al.	2000	Africa[1]	1–5%
Duflo	2001	Indonesia	8.8–12%
Other			
Baird, Hicks, Kremer, Miguel[2]	2016	Kenya	32%
Haushofer, Shapiro[3]	2016	Kenya	15%

[1]Cameroon, Ghana, Kenya, Zambia, Zimbabwe. [2]Deworming. [3]Unconditional cash transfers. Annualized internal rate of return (IRR) estimates from recent literature. The IRR corresponds to the interest rate where the Net Present Value of an investment, from time 0 to infinity, equals 0. Conversion between monthly and annualized IRR conservatively (and in line with the literature) assumes no reinvestment.

Table 4: Interaction of attention to future costs and credit

	WTP (USD)		
	(1)	(2)	(3)
Credit	12.61***	12.62***	11.07***
	(0.69)	(1.27)	(1.45)
Attention to benefits	0.40	-1.11	-0.75
	(0.86)	(1.48)	(1.48)
Attention to costs ($\beta^{\dagger}$)	-0.22	2.33*	2.23*
	(0.79)	(1.35)	(1.35)
Attention to benefits X Credit		2.28	1.92
		(1.81)	(1.81)
Attention to costs X Credit (β^{*})		-3.84**	-3.73**
		(1.66)	(1.66)
Time inconsistent (δ^{o})			-2.51**
			(1.13)
Time inconsistent X Credit ($\delta^{\triangle}$)			3.12**
			(1.38)
Observations	962	962	962
Control Mean	12.12	12.12	13.14
Sample	Full	Full	Full
F-test: $\beta^{\dagger} = \beta^{*}$		0.03	0.04
F-test: $\beta^{\dagger} + \beta^{*} = 0$		0.12	0.12
F-test: Joint significance $\delta^{o}, \delta^{\triangle}$			0.06

Causal impact of credit and attention treatments on willingness-to-pay (WTP) elicited during the Becker-DeGroot-Marschak (BDM) mechanism. For the *'attention to benefits'* treatment, the indicator variable 'Attention to benefits' is set to 1 and the indicator variable 'Attention to costs' is set to 0. For the *'attention to benefits minus costs'* treatment, both indicator variables are set to 1. Agents are defined as exhibiting time inconsistency if they choose to postpone effort tasks during their second decision point. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10$,$^{**} \leq .05$,$^{***} \leq .01$.

Robustness Checks

Table 5: Impact of stove adoption on charcoal spending 18 months after adoption

	First Stage	IV Estimate	
	Bought Stove	USD	IHS(USD)
BDM Price (USD)	-0.025***		
	(0.003)		
WTP (USD)	0.014***	0.006	0.002
	(0.004)	(0.030)	(0.008)
Bought Cookstove (=1)		-2.820***	-0.593***
		(0.860)	(0.216)
Observations	114	114	114
Control Mean	0.091	4.951	2.084
Socioeconomic controls	Yes	Yes	Yes
Data Source	Midline	Endline	Endline

Results from an instrumental variables regression that uses the (randomly assigned) BDM price as an instrument for stove adoption to estimate the long-term causal impact of stove adoption on weekly charcoal expenditures. The sample includes respondents that participated in a pilot launched in February 2018 and who successfully completed a 18-month follow-up SMS survey in July-August 2019. The IHS point estimate of a 0.593 reduction corresponds to a 45 percent reduction relative to the control group. Socioeconomic controls include weekly rent, number of adults and children, household income, baseline savings, and baseline charcoal expenditures. SE in parentheses. $^{*} \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

Table 6: Risk aversion reduces adoption, but this does not affect credit

	WTP (USD)	
	(1)	(2)
Credit	12.61***	12.57***
	(0.69)	(1.21)
Risk aversion	-1.97***	-2.00*
	(0.71)	(1.21)
Risk aversion X Credit		0.05
		(1.47)
Belief about stove durability (years)	0.41***	0.41***
	(0.16)	(0.16)
Observations	962	962
Control Mean	12.12	12.12
Sample	All	All

Results from a regression estimating how risk aversion and beliefs about stove durability affect WTP. Risk aversion affects WTP directly but does not meaningfully affect the impact of credit. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

Non-monetary impacts

Table 7: Non-monetary outcomes: Drivers and impact of stove adoption

	WTP (USD)	Health Symptoms Index (endline)			Minutes cooking per day	Adoptions in network
	(1)	(2)	(3)	(4)	(5)	(6)
Health beliefs (index)	0.098					
	(0.621)					
Savings beliefs (USD)	0.015**					
	(0.008)					
Jikokoa (=1)		-0.531***	-0.571***	-0.517***	-55.755***	-0.228
		(0.105)	(0.111)	(0.115)	(14.505)	(0.171)
Continued old stove use (=1)			0.170*	0.147*		
			(0.088)	(0.088)		
Charcoal usage (KG/month)				0.047***		
				(0.015)		
Observations	931	931	931	931	931	931
Control Mean	11.864	0.000	0.000	0.000	192.142	0.317
Socioeconomic controls	Yes	Yes	Yes	Yes	Yes	Yes

Column (1) tests whether baseline beliefs affect WTP. Columns (2) through (6) present causal estimates of the impact of stove adoption on various outcomes measured one month after adoption. The health symptoms index measures self-reported respiratory outcomes for adults and children normalized such that the control group has a mean of 0 and a standard deviation of 1. Adoptions in network indicates whether any of the respondent's friends, family, or neighbors purchased the Jikokoa in the past 1 month. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table 8: Marginal Value of Public Funds (MVPF) estimates under various assumptions

Benefits (USD)			Total Benefits (USD)			MVPF	
Financial	Time	Environmental (SCC)	Private	Social	Inframarginal Adoption	Private	Social
204	0	49 (10)	204	253	50%	3	4
204	0	49 (10)	204	253	1%	6	7
204	231	49 (10)	434	483	50%	6	7
204	231	49 (10)	434	483	1%	13	14
204	0	207 (42)	204	410	50%	3	6
204	0	207 (42)	204	410	1%	6	12
204	231	207 (42)	434	641	50%	6	9
204	231	207 (42)	434	641	1%	13	19
204	0	492 (100)	204	696	50%	3	10
204	0	492 (100)	204	696	1%	6	20
204	231	492 (100)	434	927	50%	6	14
204	231	492 (100)	434	927	1%	13	27
204	0	985 (200)	204	1,189	50%	3	18
204	0	985 (200)	204	1,189	1%	6	35
204	231	985 (200)	434	1,419	50%	6	21
204	231	985 (200)	434	1,419	1%	13	41

Estimates of the Marginal Value of Public Funds (MVPF) of a USD 30 government subsidy for the stove under various assumptions. The MVPF calculates the total welfare gain, in USD, per USD 1 of government expenditures. We adopt existing estimates from the literature of the marginal cost of funds of USD 1.13 per every USD 1 of government spending raised through taxation. The Social Cost of Carbon represents total future damages caused per metric ton of CO_2 emitted today. Benefits are accrued over a two year usage period discounted at $\delta = 0.9$ annualized. Private benefits include financial and time benefits. Social benefits consists of private benefits plus reductions in climate change damages. Variation in inframarginal adoption accounts for the fraction of government subsidies paid out to individuals that would have adopted the stove even without the subsidy (the BDM curve elicited among the control group in this study suggests an inframarginal adoption rate of 1 percent).

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Appendix Figures

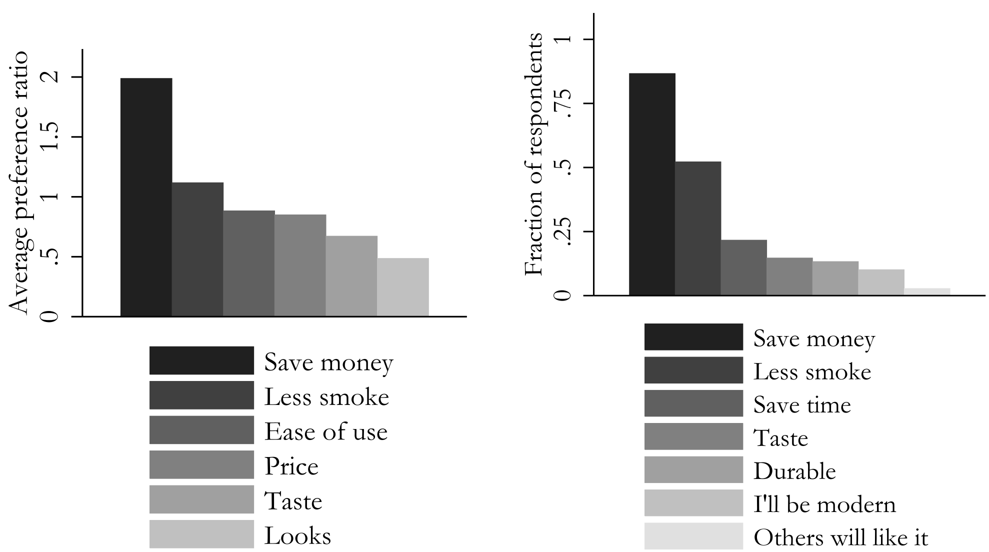
Figure A1: Informational pamphlet

To reduce information asymmetries prior to the start of surveying, all participants received this leaflet containing information about the Jikokoa stove at baseline. The graphic with charcoal tins indicating that the Jikokoa uses only 50 percent of a regular stove was designed to be understandable by literate and illiterate respondents.

Figure A2: Most salient benefits of Jikokoa stove

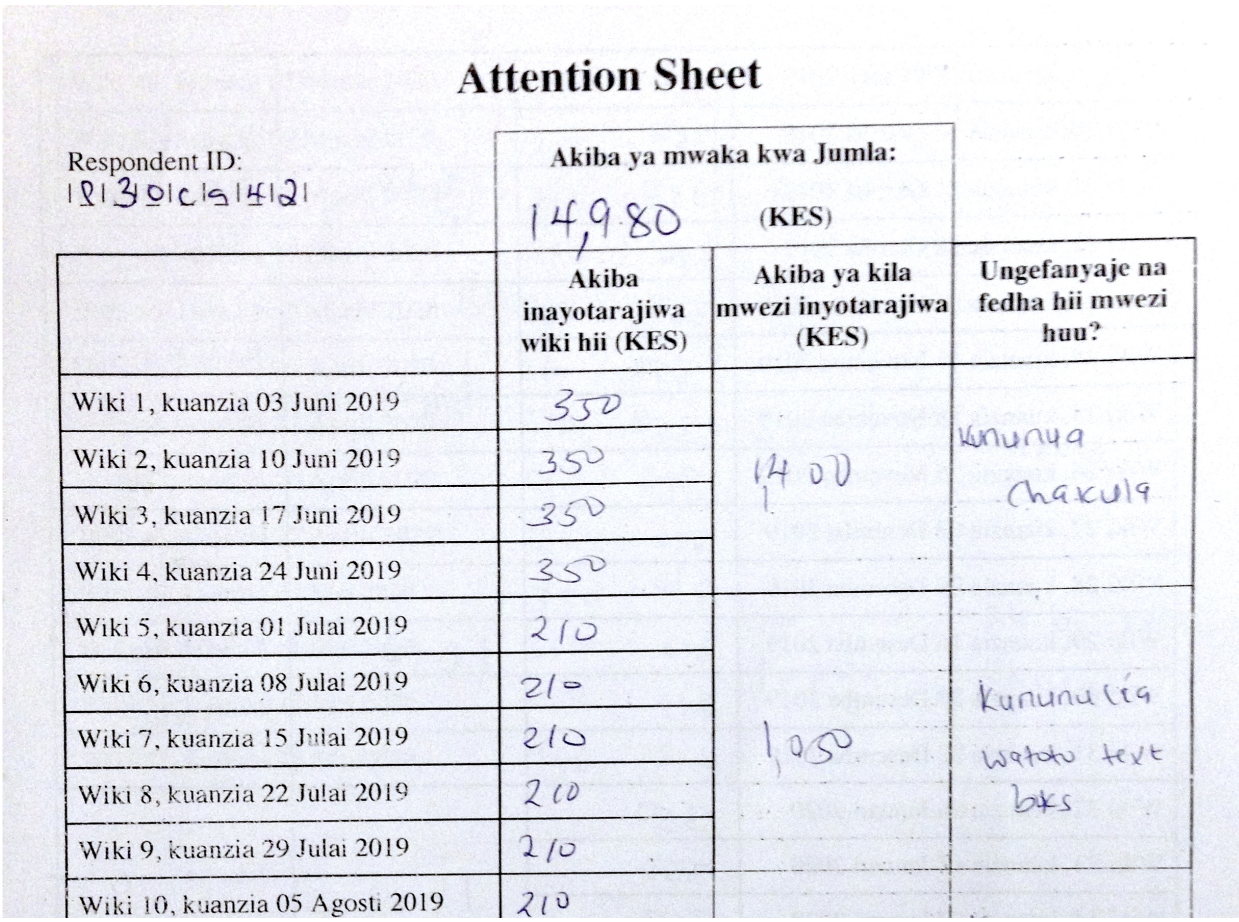
A. Important stove qualities

B. Best attributes of Jikokoa



The most salient positive attribute about the Jikokoa stove is that it saves money. This attribute is almost twice as preferred as health benefits from reductions in smoke emissions, which itself is more than twice as large as any other attribute.

Figure A3: Attention Sheet



Attention Sheet

Respondent ID: 1213010151412

Akiba ya mwaka kwa Jumla: 14,980 (KES)

	Akiba inayotarajiwa wiki hii (KES)	Akiba ya kila mwezi inyotarajiwa (KES)	Ungefanyaje na fedha hii mwezi huu?
Wiki 1, kuanzia 03 Juni 2019	350	1400	Kununua Chakula
Wiki 2, kuanzia 10 Juni 2019	350		
Wiki 3, kuanzia 17 Juni 2019	350		
Wiki 4, kuanzia 24 Juni 2019	350		
Wiki 5, kuanzia 01 Julai 2019	210	1,050	Kununulia watoto text bks
Wiki 6, kuanzia 08 Julai 2019	210		
Wiki 7, kuanzia 15 Julai 2019	210		
Wiki 8, kuanzia 22 Julai 2019	210		
Wiki 9, kuanzia 29 Julai 2019	210		
Wiki 10, kuanzia 05 Agosti 2019	210		

This figure displays the first nine weeks of the attention to benefits sheet as completed by a respondent. They are first asked to write down how much they expect to save each week. They then calculate and write down the total expected savings for each month, and what they would do with these savings. Finally, respondents calculate their total annual savings by adding all 12 monthly amounts, and write this at the top of the sheet. *"kununua chakula"* = *"buy food"* . *"Kununulia watoto text books"* = *"buy the children textbooks"*. Respondents in attention treatment groups A1 and A2 complete this sheet for all 52 weeks. 47 percent of respondents filled in the sheet entirely on their own. 31 percent of respondents filled in the sheet themselves, but required guidance by the field officer. The remaining 22 of respondents were illiterate and the field officer filled in the numbers on their behalf, while discussing the answers with the respondent. Responses are statistically indistinguishable across these three groups. KES 100 $\approx$ USD 1 at the time of surveying.

Figure A4: Attention Treatments

Panel A: Attention control (A0)

If the price of the cookstove is 2500 Ksh would you want to buy it?

You would need to pay 212 Ksh per week for the next 12 weeks.

Panel B: Attention to energy savings (A1)

If the price of the cookstove is 2500 Ksh would you want to buy it?

You would need to pay 212 Ksh per week for the next 12 weeks.

JUNE:
Week 1: You would save 200 Ksh
Week 2: You would save 300 Ksh
Week 3: You would save 200 Ksh
Week 4: You would save 300 Ksh

JULY
Week 5: You would save 300 Ksh
Week 6: You would save 300 Ksh
Week 7: You would save 400 Ksh
Week 8: You would save 400 Ksh
Week 9: You would save 300 Ksh

AUGUST
Week 10: You would save 200 Ksh
Week 11: You would save 300 Ksh
Week 12: You would save 300 Ksh

Panel C: Attention to energy savings minus costs (A2)

If the price of the cookstove is 2500 Ksh would you want to buy it?

You would need to pay 212 Ksh per week for the next 12 weeks.

Week 1: You would pay -12 Ksh. This is your weekly savings of 200 minus your weekly payment of 212.
Week 2: You would save 88 Ksh (300 Ksh - 212 Ksh)
Week 3: You would pay -12 Ksh (200 Ksh - 212 Ksh)
Week 4: You would save 88 Ksh (300 Ksh - 212 Ksh)

Week 5: You would pay -12 Ksh (200 Ksh - 212 Ksh)
Week 6: You would save 88 Ksh (300 Ksh - 212 Ksh)
Week 7: You would pay -12 Ksh (200 Ksh - 212 Ksh)
Week 8: You would save 88 Ksh (300 Ksh - 212 Ksh)

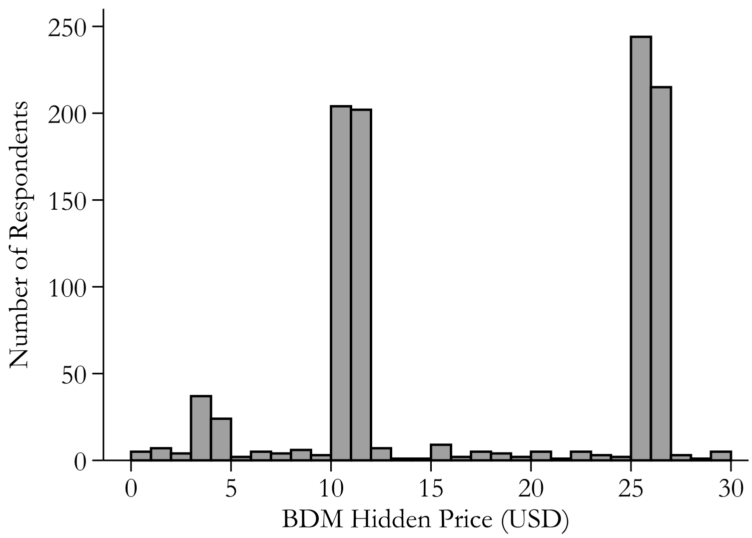
Week 9: You would pay -12 Ksh (200 Ksh - 212 Ksh)
Week 10: You would pay -12 Ksh (200 Ksh - 212 Ksh)
Week 11: You would save 88 Ksh (300 Ksh - 212 Ksh)
Week 12: You would pay -12 Ksh (200 Ksh - 212 Ksh)

After 12 weeks, you have paid off your stove, and you can keep all of your weekly savings:

Week 13: You would save 300 Ksh

The on-screen information during the BDM decision process for a hypothetical respondent in the weekly credit treatment group (C1). The payment amounts vary over 12 cycles of *Yes/No* questions depending on the respondent's answers. The benefits stay constant. The conversion from total cost to weekly payment amounts includes interest rate of 1.16 percent per month. Ksh (KES) 100 $\approx$ USD 1 at the time of surveying.

Figure A5: BDM Hidden price distribution

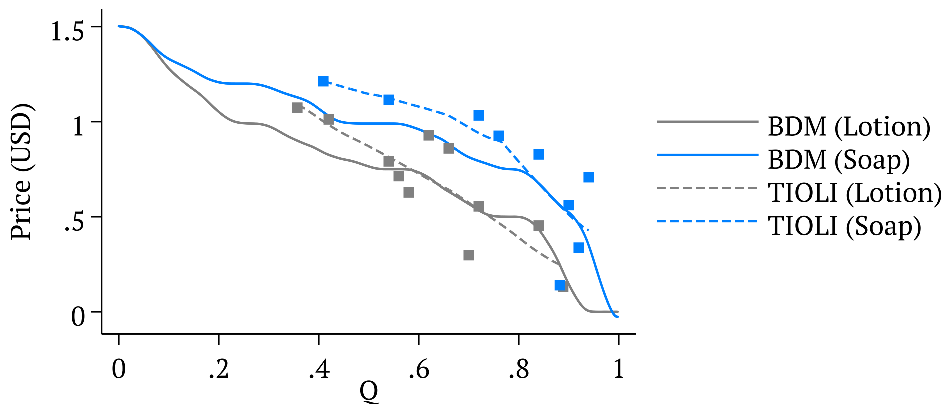


The distribution of prices P_i used in the BDM elicitation mechanism. 6 percent of participants are allocated a price drawn from $U[3.50, 4.50]$, 39 percent of participants are allocated a price drawn from $U[10, 12]$, and 44 percent of participants are allocated a price drawn from $U[25, 27]$. The remaining prices are drawn from a uniform distribution over the entire interval $U[0.01, 29.99]$. Respondents buy the stove if and only if $WTP_i \geq P_i$.

Figure A6: Becker-DeGroot-Marschak (BDM) and Take-it-or-leave-it (TIOLI) methods practice round items

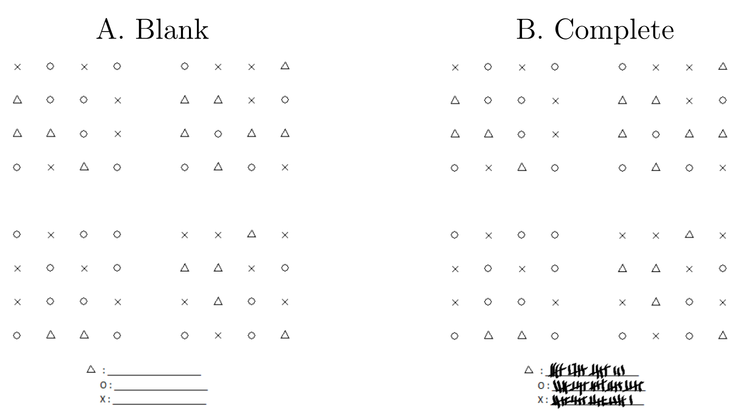
Two practice rounds help respondents understand the BDM mechanism and allow us to compare BDM responses with a TIOLI auction. These particular brands of lotion and soap are commonly used by our respondents and widely sold for a retail price of \$1.19 and \$1.48, respectively. Respondents were randomly assigned whether they would be offered the lotion using TIOLI and the bar of soap using BDM, or vice versa.

Figure A7: Demand curves elicited through Becker-DeGroot-Marschak (BDM) and Take-it-or-leave-it (TIOLI) methods



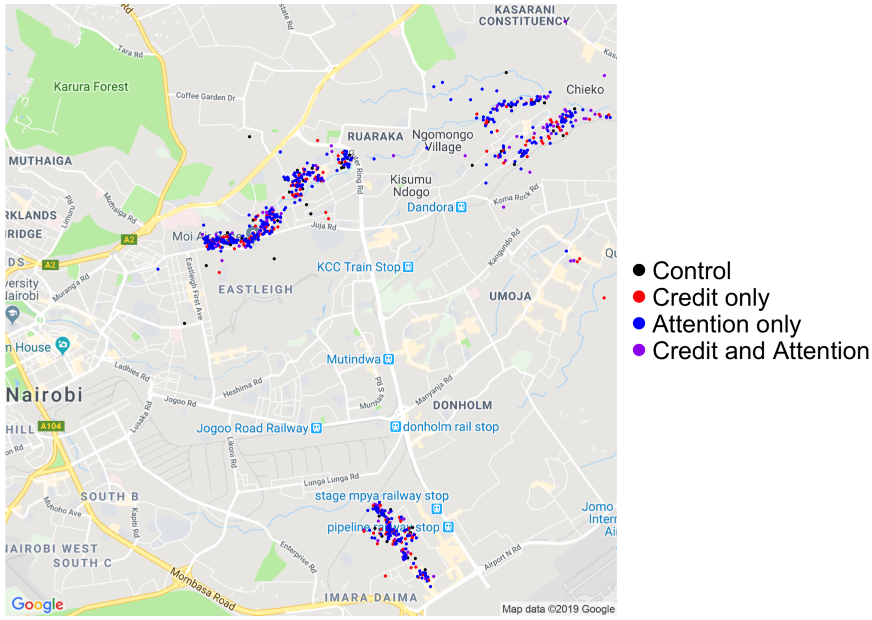
We test whether TIOLI and BDM elicit the same demand curves by cross-randomizing these with two goods. The BDM demand curve is defined as $Pr(WTP \geq P_i)$. The TIOLI demand curve takes average adoption rates across intervals of 50 observations. The overlap of the two curves suggests that the BDM mechanism elicits WTP responses that are in line with respondents' real behavior during a TIOLI decision. A statistical test cannot reject that average take-up within most price bins is equal for both elicitation methods.

Figure A8: Effort Task



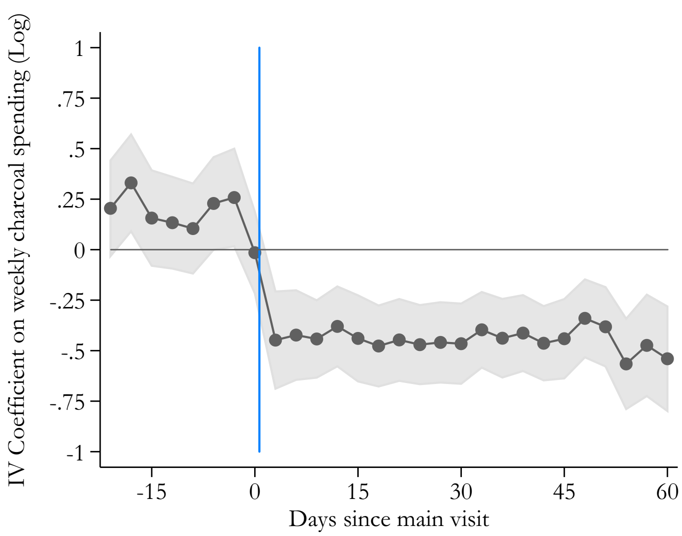
Example of one blank and one completed *effort task*. Respondents mark the number of times each symbol appears. Respondents are asked to use tick marks in order to prevent more educated or literate participants from gaining an advantage. Most respondents took between one to two minutes to complete one task. The answers had to be within 10 percent of the correct number of ticks to be marked as 'complete'. Each respondent is required to complete at least three tasks during each visit.

Figure A9: Respondent locations



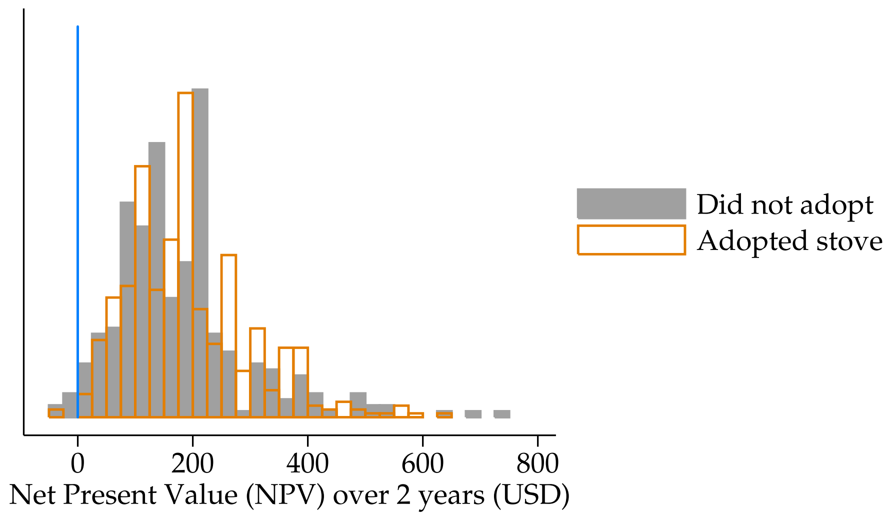
The 1,018 respondents enrolled in our study reside in one of four low-income neighborhoods in the eastern part of Nairobi: Dandora, Kayole, Mathare, and Mukuru. Respondents are randomly allocated to credit and attention treatment arms prior to the start of Visit 2.

Figure A10: Causal IV estimate of adoption on spending over time



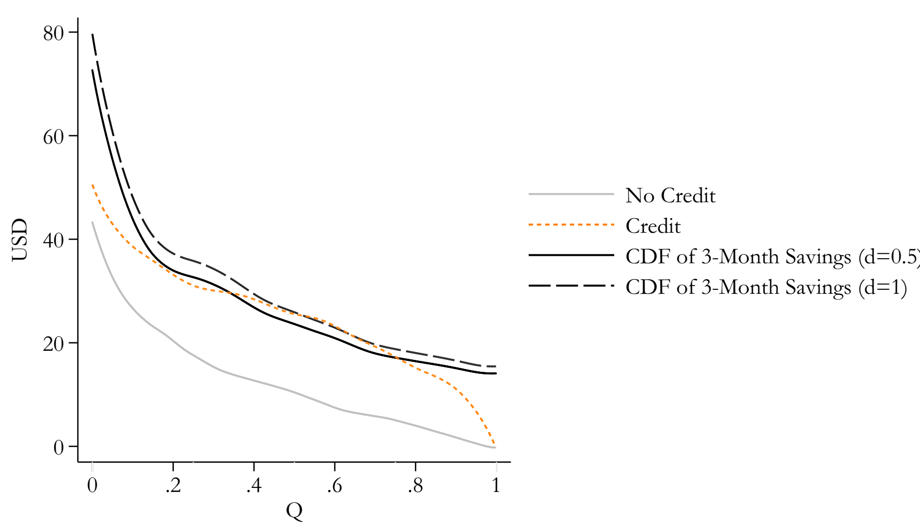
Instrumental Variables (IV) estimates for the causal effect of stove adoption on average weekly charcoal spending over time. Estimates prior to adoption have larger standard errors because only respondents in the attention treatment groups participated in the SMS survey about charcoal expenditures prior to Visit 2, which reduces the sample size.

Figure A11: Distribution of stove's Net Present Value (NPV) across respondents



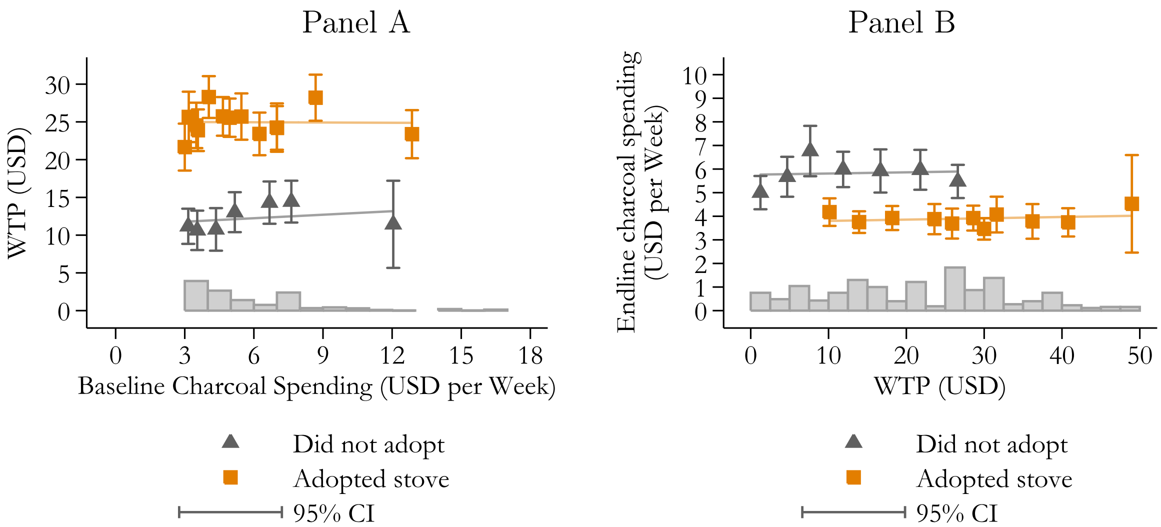
Distribution of the stove's net present value (NPV) for all respondents that report charcoal expenditures after Visit 2. We define $NPV = \left[\sum_{t=1}^{T} \delta^t \psi_t\right] - P_E$, where $\psi_t = \gamma \hat{S}_i$ as in Equation 2. We use $\delta = 0.9$ annualized, $\gamma = 0.39$ savings as estimated above, $P_E = 40$ USD. We define $\hat{S}_i$ equal to each respondent's post-adoption counterfactual charcoal spending. We estimate NPV over $T = 104$ weeks post-adoption. NPV equals USD 178 per respondent on average, and is positive for > 99 percent of respondents.

Figure A12: Robustness of under-adoption gap for varying annual δ



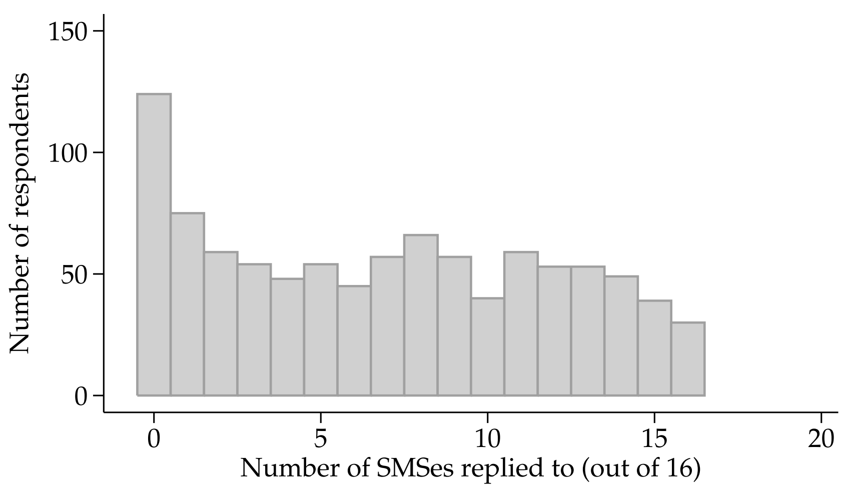
Demand curves assuming annual discount factors of $\delta = 0.5$ and $\delta = 1$. Because we quantify under-adoption in the short term (13 weeks), varying annual discount factors across a wide interval does not meaningfully affect results.

Figure A13: Treatment effect by WTP



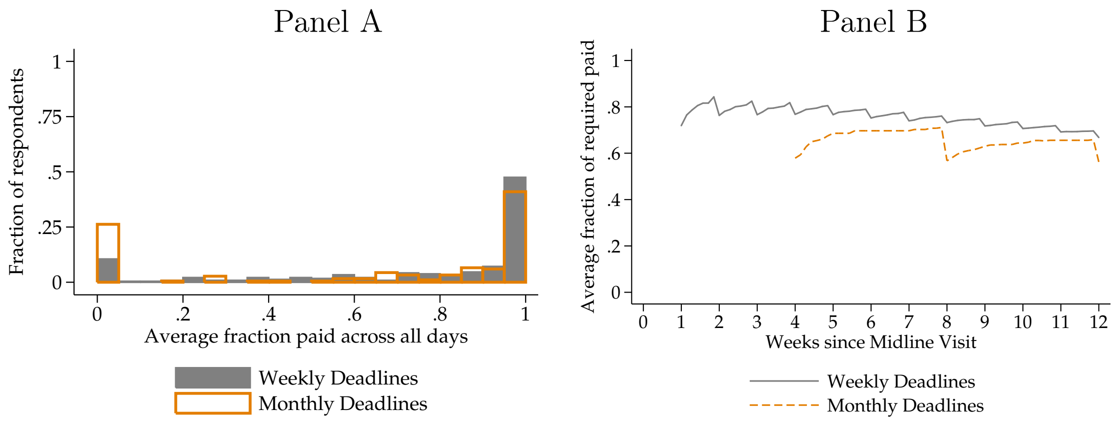
In Panel A, expected returns does not predict WTP. In Panel B, WTP does not predict realized returns.

Figure A14: Number of SMSes replied to, by respondent



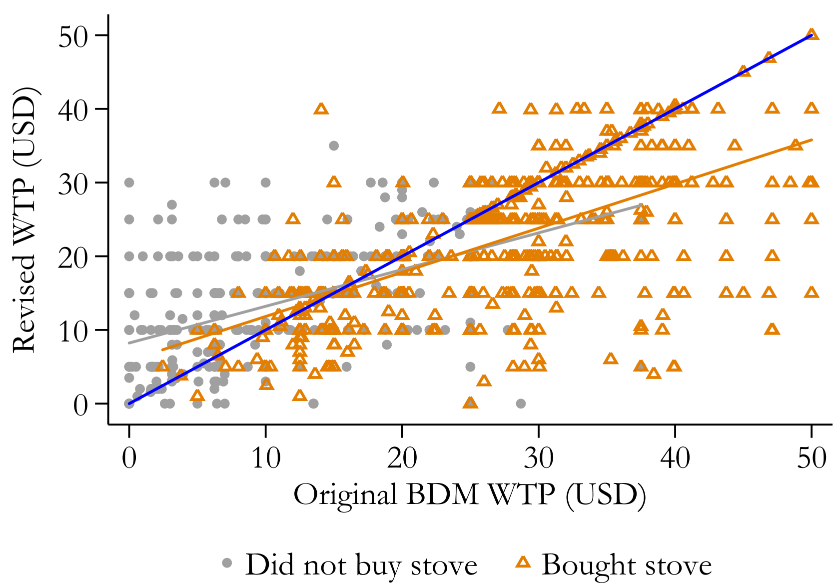
The number of SMSes each respondent correctly responded to during the first 48 days (16 3-day SMS cycles) after visit 2. Out of 962 respondents who completed Visit 2, 124 (13 percent) did not respond to any SMSes in this period. 446 respondents (46 percent) responded to at least half of all SMSes. Figure A6 confirms that socio-economic characteristics (with the exception of age) do not predict SMS non-response.

Figure A15: Loan repayment patterns



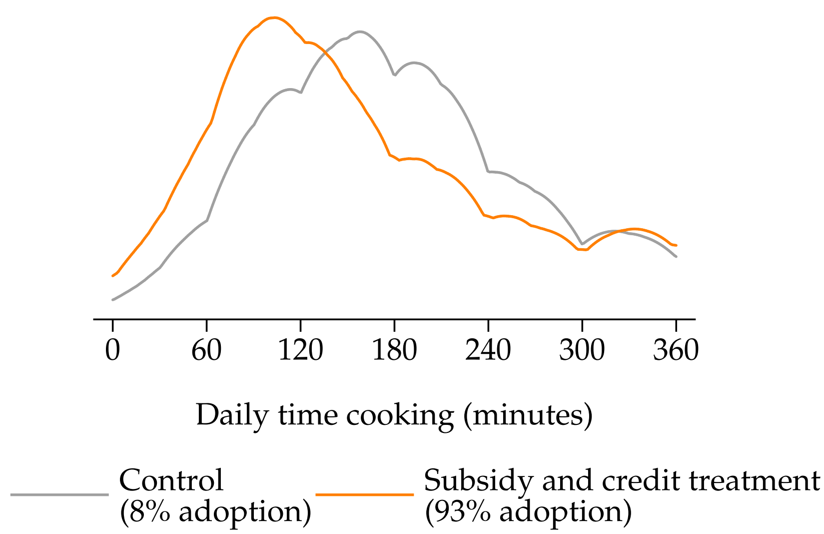
Panel A displays the fraction of the rolling minimum that the respondent has paid, averaged across all 84 days. Only days after the respondent's first payment deadline count towards the denominator. 51 percent of respondents had paid at least 90 percent on average and 60 percent of respondents had paid at least 80 percent on average. Panel B displays the average fraction of the required amount that respondents had paid for every day of the 3-month payment period. These data exclude the 9 percent of stove winners in the credit treatment groups who opted to pay the full price up front, or the 3 respondents who returned the stove because of an inability to pay.

Figure A16: Change in WTP from midline to endline



Respondent WTP as measured during the BDM mechanism and as stated during the endline survey. Conditional on BDM WTP, stove adoption is random. Endline WTP is similar for stove adopters and non-adopters. This rules out substantial learning or hidden attributes.

Figure A17: Time savings from stove adoption



Time spent cooking per day, self-reported during the endline survey. We plot usage by randomly assigned treatment since stove adoption is correlated with WTP, but compliance is high. The instrumental variables regression suggests that adoption of the stove causes households to reduce their daily time spent cooking by 56 minutes. This is the opposite of the rebound theory in energy efficiency, which states that household usage of an appliance goes up after adoption of a more energy efficient version, since the marginal cost of usage goes down. The reduction is likely due to the ease of lighting the stove, rather than a change in cooking time itself.

Appendix Tables

Table A1: Balance test for attention, credit, and subsidy treatments

	Sample Mean	Attention Treatment	Credit Treatment	Subsidy Treatment	N
	(1)	(2)	(3)	(4)	
Sex (female=1)	0.95	0.02	-0.01	-0.01	1018
	[0.21]	(0.01)	(0.01)	(0.01)	
Respondent age	37.24	-0.25	0.22	-0.03	1018
	[11.83]	(0.82)	(0.79)	(0.74)	
Number of household residents	4.73	-0.04	0.11	0.07	1018
	[2.08]	(0.14)	(0.14)	(0.13)	
Number of child residents	2.57	-0.02	0.10	0.09	1018
	[1.72]	(0.12)	(0.11)	(0.11)	
Savings in bank, mobile, ROSCA (USD)	74.65	2.07	5.70	-12.14	1018
	[129.12]	(8.94)	(8.60)	(8.09)	
Household income (USD/week)	47.12	-2.33	-4.02*	-1.64	1012
	[34.57]	(2.40)	(2.31)	(2.17)	
Total energy consumption (USD/week)	8.54	0.08	0.12	-0.18	1018
	[3.59]	(0.25)	(0.24)	(0.22)	
Charcoal consumption (USD/week)	5.59	0.05	0.04	-0.10	1018
	[2.60]	(0.18)	(0.17)	(0.16)	
Price of old jiko (USD)	3.40	0.08	-0.01	0.05	1013
	[1.34]	(0.09)	(0.09)	(0.08)	
Risky investment amount (0-4 USD)	1.19	0.04	-0.10	-0.11*	1018
	[1.00]	(0.07)	(0.07)	(0.06)	
Joint F-Test		0.82	0.51	0.13	

Each row and each treatment column represents an individual regression of the row variable on an indicator for receiving the treatment in the column. For legibility, in this table the sub-treatments for attention and credit are pooled. Treatment assignment was stratified on baseline charcoal spending. The three treatments appear to be balanced on observable demographic and socioeconomic characteristics. SD in brackets. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A2: Causal impact of stove adoption on charcoal use

	OLS	First Stage	IV Estimate							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	USD	Bought Stove	USD	USD	Log(USD)	Log(USD)	Log(KG)	IHS(USD)	IHS(USD)	IHS(KG)
BDM Price (USD)	0.004	-0.029***								
	(0.013)	(0.001)								
WTP (USD)	-0.003	0.025***	0.007	-0.006	0.002	0.002	0.004	0.002	0.001	0.004
	(0.010)	(0.001)	(0.010)	(0.011)	(0.002)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)
Bought Cookstove (=1)	-1.926***		-2.423***	-1.528***	-0.591***	-0.439***	-0.566***	-0.531***	-0.394***	-0.490***
	(0.293)		(0.306)	(0.330)	(0.070)	(0.082)	(0.099)	(0.074)	(0.089)	(0.083)
Observations	7923	920	7923	918	7789	883	803	7923	918	803
Control Mean	5.716	0.400		4.313	1.485	1.338	0.759	2.154	1.984	1.546
Socioeconomic controls	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data Source	SMSes	Midline		Endline	SMSes	Endline	Buckets	SMSes	Endline	Buckets

Column (1) presents the OLS estimate of charcoal spending on random price, WTP, and stove adoption. Column (2) presents the first stage in the instrumental variables regression, using the (randomly assigned) BDM price as an instrument for stove adoption. Columns (3) and (4) provide estimates of the impact of stove adoption on charcoal usage in USD. Columns (5) through (10) provide estimates of the impact of stove adoption on charcoal usage with logarithmic and IHS conversion. Columns (7) and (10) provide estimates of the impact of stove adoption on charcoal consumption as measured by the weight of the ash generated from stove usage. Results are robust to including or not including socioeconomic controls, baseline charcoal spending measured during Visit 1, and pre-Visit 2 charcoal spending measured through the SMS survey. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. In regressions using SMS data, errors are clustered by respondent. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A3: Impact of experimental treatments on WTP

	WTP (USD)				
	(1)	(2)	(3)	(4)	(5)
Credit (pooled)	12.60***				12.62***
	(0.69)				(1.27)
Credit (C1 only)		13.20***			
		(0.79)			
Credit (C2 only)		11.99***			
		(0.80)			
Attention (pooled)			0.15		0.29
			(0.83)		(1.24)
Attention (A1 only)				0.26	
				(1.00)	
Attention (A2 only)				0.07	
				(0.91)	
Attention (pooled) X Credit (pooled)					-0.03
					(1.51)
Observations	962	962	962	962	962
Control Mean	12.33	12.33	20.54	20.54	12.12
Sample	Full	Full	Full	Full	Full

Impact of pooled treatments on WTP. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A4: Interaction of attention to future costs and time-inconsistency

	WTP (USD)		
	(1)	(2)	(3)
Credit	11.07***	10.49***	14.77***
	(1.45)	(1.89)	(1.73)
Attention to benefits	-0.75	-0.97	-0.60
	(1.48)	(2.30)	(1.96)
Attention to costs ($\beta^{\dagger}$)	2.23*	2.85	1.81
	(1.35)	(2.23)	(1.70)
Attention to benefits X Credit	1.92	1.81	1.89
	(1.81)	(2.85)	(2.36)
Attention to costs X Credit (β^{*})	-3.73**	-2.35	-4.78**
	(1.66)	(2.70)	(2.10)
Time inconsistent (δ^{o})	-2.51**		
	(1.13)		
Time inconsistent X Credit ($\delta^{\triangle}$)	3.12**		
	(1.38)		
Observations	962	413	549
Control Mean	13.14	13.14	10.98
Sample	Full	TI=0	TI=1
F-test: $\beta^{\dagger} = \beta^{*}$	0.04	0.27	0.07
F-test: $\beta^{\dagger} + \beta^{*} = 0$	0.12	0.74	0.02
F-test: Joint significance $\delta^{o}, \delta^{\triangle}$	0.06		

Causal impact of credit and attention treatments on WTP elicited during the BDM mechanism. For the *'attention to benefits'* treatment, the indicator variable 'Attention to benefits' is set to 1 and the indicator variable 'Attention to costs' is set to 0. For the *'attention to benefits minus costs'* treatment, both indicator variables are set to 1. Agents are defined as exhibiting time inconsistency (TI=1) if they choose to postpone effort tasks during their second decision point. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10, ^{**} \leq .05, ^{***} \leq .01$.

Table A5: Test of Concentration Bias

	WTP (USD)			
	(1)	(2)	(3)	(4)
Weekly Credit (C1 only)	13.19***	13.20***		
	(0.80)	(0.79)		
Monthly Credit (C2 only)	12.10***	11.99***	-1.09	-1.24
	(0.80)	(0.80)	(0.82)	(0.81)
Observations	962	962	641	641
Control mean	12.33	12.33	20.85	20.85
Sample	Full	Full	C1 & C2	C1 & C2
Controls	No	Yes	No	Yes
F-test weekly = monthly:	0.17	0.13		

Causal impact of credit with weekly and with monthly deadlines on WTP. Socioeconomic controls include baseline savings, income, risk aversion, credit constrainedness, number of adults and children. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

Table A6: Socio-economic characteristics do not predict attrition

	Sample Mean	Attrited (Visit 2)	Attrited (Visit 3)	Attrited (SMSes)	N
BDM Treatment (Price <= 15 USD)	0.50	0.07	-0.01	0.00	1018
	[0.50]	(0.07)	(0.06)	(0.03)	
Credit Treatment	0.67	0.05	0.01	-0.04	1018
	[0.47]	(0.06)	(0.05)	(0.03)	
Attention Treatment	0.71	0.12*	0.09*	0.01	1018
	[0.46]	(0.06)	(0.05)	(0.03)	
Sex (female=1)	0.96	-0.01	-0.00	-0.00	1018
	[0.21]	(0.03)	(0.02)	(0.01)	
Respondent age	37.47	-4.13**	-3.53***	-1.75**	1018
	[11.85]	(1.62)	(1.32)	(0.74)	
Number of household residents	4.75	-0.34	-0.40*	-0.17	1018
	[2.07]	(0.29)	(0.23)	(0.13)	
Number of child residents	2.60	-0.35	-0.32	-0.02	1018
	[1.72]	(0.24)	(0.19)	(0.11)	
Savings in bank, mobile, ROSCA (USD)	75.39	-14.54	-17.26	-3.21	1018
	[129.81]	(17.75)	(14.47)	(8.12)	
Household income (USD/week)	47.22	-1.96	-2.24	-1.53	1012
	[34.72]	(4.75)	(3.88)	(2.18)	
Total energy consumption (USD/week)	8.55	-0.05	-0.44	0.13	1018
	[3.59]	(0.49)	(0.40)	(0.23)	
Charcoal consumption (USD/week)	5.60	-0.20	-0.37	0.03	1018
	[2.59]	(0.36)	(0.29)	(0.16)	
Price of old jiko (USD)	3.40	0.06	-0.10	-0.02	1013
	[1.36]	(0.18)	(0.15)	(0.08)	
Risky investment amount (0-4 USD)	1.19	0.04	0.03	-0.00	1018
	[0.99]	(0.14)	(0.11)	(0.06)	
Joint F-Test		0.41	0.23	0.69	

Each coefficient in each of the Attrited columns represents a separate regression testing whether the outcome variable predicts attrition. Attrited (SMS) equals one for respondents who responded than fewer of the median number of SMSes. SE in parentheses. $^{*} \leq 0.10,^{**} \leq .05,^{***} \leq .01$.

8.1 Additional appendices

8.1.1 Derivations of the micro-foundations of inattention

We explore the micro-foundations that determine the attention parameter θ_i across individuals. We allow for imperfect attention following Gabaix and Laibson 2017. We define $b_t = u(c_t + \psi_t) - u(c_t)$ to capture the beneficial utility consequences from purchasing the stove, and $\kappa_t = u(c_t + \psi_t - r_t) - u(c_t + \psi_t)$ to capture the costly utility consequences from purchasing the stove. We assume that the agent perfectly perceives the current period, but that both b_t and κ_t are imperfectly observed for $t = 1, ..., T$. By paying attention to each period, the agent is able to generate signals about the utility benefits and costs of purchasing the stove (s_t^b and s_t^κ respectively). The condition then changes to:

$$u(c_0 - p^* + l) - u(c_0) + \sum_{t=1}^{T} D(t)\left[\mathbb{E}[b_t|s_t^b] - \mathbb{E}[\kappa_t|s_t^\kappa]\right] \;=\; 0 \tag{8}$$

We further assume that these signals are correct on average and are imperfectly observed due to independent, normally distributed noise that is linearly increasing in later periods:

$$s_t^b \;=\; \mathbb{E}[u(c_t + \psi_t) - u(c_t)] + \epsilon_t \qquad \epsilon_t \sim N(0, \sigma_\epsilon^2 t) \tag{9}$$

$$s_t^\kappa \;=\; \mathbb{E}[u(c_t + \psi_t - r_t) - u(c_t + \psi_t)] + \nu_t \qquad \nu_t \sim N(0, \sigma_\nu^2 t) \tag{10}$$

The agent then combines these signals with the priors they hold over the benefits and costs of adopting new technologies. This yields the following prediction:

> **Prediction 2:** When attention to benefits is increased (smaller σ_ϵ^2), if the true benefits of the stove are greater than the prior for all technologies this will increase WTP.
>
> $$\frac{\partial p^*}{\partial \sigma_\epsilon^2} < 0$$

The impact of attention to costs on adoption will depend on whether costs are incurred in the present or in the future. Specifically,

> **Prediction 3:** If the agent does not have access to credit and there are no other flow costs, $r_t = 0 \;\forall\; t$. Thus if $0 < \mu$, increasing attention to costs will lower σ_ν^2 and increase WTP.[97]
>
> $$\frac{\partial p^*}{\partial \sigma_\nu^2} < 0$$

> **Prediction 4:** If the agent has access to credit and $\mu < r_t$, then increased

[97] Intuitively, the agent expects there to be some flow cost of adoption and after thinking about it realizes there actually isn't.

attention to costs will lower σ_ν^2 and decrease WTP.[98]

$$\frac{\partial p^*}{\partial \sigma_\nu^2} > 0$$

Because the signals are stochastic so is the agent's willingness to pay. Thus, for clarity, we follow Gabaix and Laibson 2017 in studying the behavior of a "representative agent" who happens to receive signals of the costs and benefits with no noise. We begin by considering the case of an agent who has not had their attention augmented. For simplicity we assume that without augmentation the signals have the same noise, $(\sigma_\epsilon^2 = \sigma_\nu^2 = \sigma_s^2)$. In this case the agent's condition simplifies to:

$$0 \;=\; u(c_0 - p^* + l) - u(c_0) + \sum_{t=1}^{T} D(t)\left[\frac{\mathbb{E}[u(c_t + \psi_t - r_t) - u(c_t)]}{1 + \frac{\sigma_s^2}{\sigma_u^2}t}\right] \tag{11}$$

The agent then combines these signals with the priors they hold over the benefits and costs of adopting new technologies. We assume that agents believe the utility benefits and costs of new technologies are identically and normally distributed $b_t, \kappa_t \sim N(\mu, \sigma_u^2)$. This plausibly holds in equilibrium for an agent who is risk neutral and is not credit constrained.[99] To illustrate, consider an agent who believes the utility benefits of new technologies on average exceed their costs; they should continually be attempting to adopt new technologies. Similarly, agents are unlikely to adopt so many technologies that they begin encountering net negative returns to adoption.

After combining these signals with the prior, the condition becomes:

$$0 \;=\; u(c_0 - p^* + l) - u(c_0) + \sum_{t=1}^{T} D(t)\left[\frac{s_t^b - \mu}{1 + \frac{\sigma_\epsilon^2}{\sigma_u^2}t} - \frac{s_t^\kappa - \mu}{1 + \frac{\sigma_\nu^2}{\sigma_u^2}t}\right] \tag{12}$$

Note that by setting $\sigma_\nu = \sigma_\epsilon = 0$ this model nests the perfect attention case. If the agent perceives perfectly correct and precise signals, the influence of the priors cancel and we're left with the same condition as in the rational case.

(11) demonstrates that agents with this kind of inattention will systematically undervalue the future utility changes induced by adopting a technology. In the case where the stove generates improvements in utility in future periods, this will reduce willingness to pay.

[98] Intuitively, one benefit of borrowing is that the costs are less acutely perceived by the agent because they are in the future. By forcing the agent to remember they will have to eventually make the loan payments, this counteracts that effect.

[99] Under risk aversion and credit constraints, it is possible that $E[\mu_b] > E[\mu_\kappa]$, with analogous implications for the impact of attention.

8.1.2 BDM Script

Section 1: Practice TIOLI (`take it or leave it') with [item1] and practice BDM with [item2]

Households are randomly assigned into one of the following two groups:

Group 1:	item1 = soap	item2 = lotion
Group 2:	item1 = lotion	item2 = soap

Each household is also randomly assigned a price for the TIOLI item [pracprice1] and a price for the BDM item [pracprice2].

Introduction

We will first give you the opportunity to buy a Lotion and a Soap. After that, we will sell the Jikokoa. As thank you for your time today, you will receive Ksh 300. If you choose to buy a Lotion or a Soap, this will be paid out of the Ksh 300. For example, if you buy the Lotion for 100 and you do not buy the Sabuni, then you will receive the Lotion and your thank you payment at the end of the day will be 200 Ksh (300 - 100). Do you have any questions?

Practice TIOLI

[FO: Show the [item1] to the respondent]

Let's start with the [item1]. Would you like to buy this [item1] for Ksh [pracprice1]?

If you say 'yes', you will pay [pracprice1] and receive the [item1]. If you say 'no', you will not receive it and not pay anything.

Would you like to buy this item?

Practice BDM

[FO: Please take 1 blank piece of paper that says:

PRICE:

__________ KSH

WITHOUT SHOWING THE RESPONDENT, WRITE DOWN THE PRICE ON THE PIECE OF PAPER: [pracprice2]

FOLD THE PAPER CLOSED. WRITE DOWN "[item2]" on the OUTSIDE. Then, put the FOLDED paper on the table. Just to confirm, please write down the price that you just wrote on the piece of paper: _______]

The process for buying the [item2] and the Jikokoa today will be a little bit different. First, you and I will figure out the highest price that you are willing to pay. Then, we will together open a secret piece of paper to look at the price. If the secret price is higher than what you said you are willing to pay, then you will NOT be able to buy the Jikokoa or the [item2] from us today. If you named a price that was the same or higher as the price that is on the paper, then you will be able to purchase the cookstove from us today. You would then pay the price written on the piece of paper. This may be even lower than the price you chose! You will not have to pay anything more than you want to.

Since this is complicated, we will first make a plan for which price you would like to pay. I will ask you whether you would be willing to pay several prices and you will tell me "yes" or "no" for each price. After we are done, you will not be able to change your plan. You will only be able to buy the cookstove or the [item2] if you are willing to pay more than the secret price.

This offer is availabe for today only. If you do not get the stove today, you will not be able to get it tomorrow. This lottery is for today only. Do you understand?

[FO: If the respondent does not understand, please re-explain or answer their questions].

This offer is for your household only. This lottery cannot be used by anyone else.

[FO: Show the [item2] to the respondent]

Let's start by doing a practice exercise for this [item2]. The price of this good is written on this piece of paper.

[FO: SHOW THE FOLDED PIECE OF PAPER BUT KEEP IT CLOSED]

Afterwards, we will do the same for the cookstove. We will use a different secret price for the Jikokoa. Do you have any questions?

Note: For this next section, the quantity in each question depends on the answer immediately prior. If the prior answer is “no”, the subsequent price will be lower. If the prior answer is “yes”, the subsequent price will be higher. This process proceeds with a binary search.

If the price was 75 Ksh, would you want to buy the [item2]?
If the price was [prac_x1] Ksh, would you want to buy it?
If the price was [prac_x2] Ksh, would you want to buy it?

If the price was [prac_x3] Ksh, would you want to buy it?
If the price was [prac_x4] Ksh, would you want to buy it?
If the price was [prac_x5] Ksh, would you want to buy it?
If the price was [prac_x6] Ksh, would you want to buy it?

Confirmation section

So the most you are willing to pay to buy the [item2] is [prac_wtp1]?

So how much is the most you are willing to pay?
Just to make sure you understand, what happens if the price ends up being [prac_wtp1_p5]?

[If not correct:]
This is not correct! If you are willing to pay [prac_wtp1] and the price turns out to be [prac_wtp1_p5] then you would NOT be able to buy the stove from us! You previously said that you were not willing to pay [prac_wtp1_p5]. Do you understand?

And what happens if the price ends up being [prac_wtp1_m5]?

[If not correct:]
This is not correct! If you are willing to pay [prac_wtp1] and the price turns out to be [prac_wtp1_m5] then you SHOULD buy the stove from us! You previously said that you were willing to pay [prac_wtp1_m5]. Do you understand?

Just to double check, if the price ends up being [prac_wtp1_p5], would you want to buy the [item2] for [prac_wtp1_p5]?

[If yes:]
So the most you are willing to pay to buy the [item2] is [prac_wtp2]?

[If no:]
So how much is the most you are willing to pay?

Just to make sure you understand, what happens if the price ends up being [prac_wtp2_p5]?

[note: the Confirmation Section can happen up to 4 times. If the respondent still changes their mind, the field officer will start again from the beginning.]

Great! So the final highest price you will pay is [prac_finwtp].

Outcome Section

We have figured out that the maximum amount that you are willing to pay for the [item2] is [prac_finwtp] Ksh. We will now open the piece of paper to see the price.

[FO: Give the respondent the piece of paper and ask them to read the number.]

[If win:]
Congratulations! The price is [pracprice2] Ksh which is less than you said you were willing to spend ([prac_finwtp] Ksh).You may have this [item2] and we will deduct [pracprice2] Ksh from your thank you payment at the end of the survey.
[FO: DO NOT LET THE RESPONDENT CHANGE THEIR MIND AT THIS POINT!!!]
Do you have any questions?

[If lose:]
Unfortunately, the price is [pracprice2] Ksh which is more than you said you were willing to spend ([prac_finwtp] Ksh). You will not be able to buy the [item2] today.
[FO: DO NOT LET THE RESPONDENT CHANGE THEIR MIND AT THIS POINT!!!]

Do you have any questions?

[FO: Did the respondent want to change their mind?
Did the respondent argue?
What was the respondent's argument?]

Section 2: Actual BDM with the Jikokoa

[FO: PLACE THE COOKSTOVE PRICE ENVELOPE IN FRONT OF YOU. KEEP IT CLOSED. The name on the envelope should be [hhname]. Is this the name written on the envelope?

YOU MUST HAVE THE CORRECT ENVELOPE FOR THIS RESPONDENT: [hhname].

If you do not have their envelope, END THE SURVEY, APOLOGIZE, and tell them we will return TOMORROW (or MONDAY).

[if the FO has the wrong envelope] STOP THE SURVEY. Save the survey, and continue later. INFORM THE SFO that this has happened. Then, continue to your next respondent, and tell this respondent that you will return later.]

We are now going to use the same method that we used for the [item2] to see what price you would like to pay for buying the Jikokoa cookstove. The secret price of the Jikokoa for you is inside this envelope. I do not know what the price is. It was randomly chosen using a computer by one of my colleagues. As you can see, the envelope is closed and has your name on it. The price may be lower than the price in the stores!

The price inside this envelope was selected by a random lottery. This means that every participant in our study has a different price inside their envelope, and the prices were selected by random chance. Therefore, the price inside your envelope will be DIFFERENT from the prices that are written inside the envelopes of other people who also participate in the study. Everybody has a different price.

Remember:
- If the price on the envelope is higher than the most you said you were willing to pay, then you will NOT be able to buy the stove today. You cannot change your mind later, and you cannot get another chance tomorrow. This offer is for today only, and it is for you only.
- If you are willing to pay the amount in the envelope, then you SHOULD buy the cookstove from us today.
[Respondents in C0:] - You SHOULD then pay the price that is in the envelope TODAY.

Remember:
- If the price on the envelope is higher than the most you said you were willing to pay, then you will NOT be able to buy the stove today. You cannot change your mind later, and you cannot get another chance tomorrow. This offer is for today only, and it is for you only.
- If you are willing to pay the amount in the envelope, then you SHOULD buy the cookstove from us. You will then pay the price that is in the envelope.
[Respondents in C0:] - To purchase the stove, you will need to have the money to pay us via MPESA TODAY. We understand that if we came back in one week, perhaps you will have more money available. For now, we would like you to just think only about the cash that you have available RIGHT NOW, to spend on MPESA. Only think of the money that you have that you can use to buy the cookstove TODAY.

[FO: give respondent some time to think].

[Respondents in C0:] When we go through the exercise, please only offer to pay what you have available to buy the cookstove today.

We are not affiliated with the Jikokoa company and to us it does not matter whether you would like to buy the stove or not. We are not sales people: we are researchers and we are just trying to learn about people like you. If you do not want to buy the stove today, or if you think the price is too high, that is okay. It does not matter to us whether you buy the stove or not.

We will do our best to keep all our answers completely confidential. We will not share your name or individual information with anyone, and none of your neighbors, family, or friends will ever be able to see your answers. When you are answering the questions, please answer honestly. We are simply trying to learn from the people we are interviewing.

There is no such thing as "too low" or "too high", and there are no right or wrong answers. Throughout this process, you will be able to look at this screen to see the different prices.

[For respondents in A2 and in C1, C2:] The screen will also show how much you will have to pay for each payment. It will also show how much you will probably save in each week. The computer will then take the savings that you expect in every week, and then subtract any payments that you have to make each week. If your savings are larger than your payments for that week, it will show you how much you will save that week. If your payment is larger than how much you will save, it will show you how much you have to pay that week.

Do you understand?

[FO: If the respondent does not understand, please re-explain, and answer any questions].

Do you have any other questions? Let's begin.

<u>*Decision Section*</u>

[FO: Place the ATTENTION SHEET on the table so the respondent can see it.
REMEMBER: Go through the savings slowly, make sure the respondents understands how it works.

[For respondents in A2:] The screen will show the savings, and then subtract the cost of payment. Explain this carefully -- make sure the respondent understands.]

If the price of the Jikokoa is [x0] Ksh would you want to buy it?

[For respondents in C1:] You would need to pay [x0w] Ksh per week for the next 12 weeks.
[For respondents in C2:] You would need to pay [x0m] Ksh per month for the next 3 months.

[For respondents in A1:] Show all the savings over all weeks.

[For respondents in A2, C0:]

Week 1: [SnetC_x0] [netC_x0] Ksh . This is your savings of [attw1] Ksh minus the cost of the stove [x0] Ksh.
After you pay for your stove today, you can keep all of your weekly savings:
[Show all the savings over all remaining weeks.]

[For respondents in A2 and in C1:]

Week 1: [Snet1_x0] [net1_x0] Ksh. This is your weekly savings of [attw1] minus your weekly payment of [x0w].
Week 2: [Snet2_x0] [net2_x0] Ksh ([attw2] Ksh - [x0w] Ksh)
Week 3: [Snet3_x0] [net3_x0] Ksh ([attw3] Ksh - [x0w] Ksh)
Week 4: [Snet4_x0] [net4_x0] Ksh ([attw4] Ksh - [x0w] Ksh)

Week 5: [Snet5_x0] [net5_x0] Ksh ([attw5] Ksh - [x0w] Ksh)
Week 6: [Snet6_x0] [net6_x0] Ksh ([attw6] Ksh - [x0w] Ksh)
Week 7: [Snet7_x0] [net7_x0] Ksh ([attw7] Ksh - [x0w] Ksh)
Week 8: [Snet8_x0] [net8_x0] Ksh ([attw8] Ksh - [x0w] Ksh)

Week 9: [Snet9_x0] [net9_x0] Ksh ([attw9] Ksh - [x0w] Ksh)
Week 10: [Snet10_x0] [net10_x0] Ksh ([attw10] Ksh - [x0w] Ksh)
Week 11: [Snet11_x0] [net11_x0] Ksh ([attw11] Ksh - [x0w] Ksh)
Week 12: [Snet12_x0] [net12_x0] Ksh ([attw12] Ksh - [x0w] Ksh)

After 12 weeks, you have paid off your stove, and you can keep all of your weekly savings:
[Show all the savings over all remaining weeks.]

[For respondents in A2 and in C2:]

Week 1: You would save [attw1] Ksh. You can keep all of your savings from the stove.
Week 2: You would save [attw2] Ksh
Week 3: You would save [attw3] Ksh
Week 4: [Snet4_x0] [net4_x0] Ksh. This is your weekly savings of [attw4] minus your monthly payment of [x0m] Ksh

Week 5: You would save [attw5] Ksh
Week 6: You would save [attw6] Ksh
Week 7: You would save [attw7] Ksh
Week 8: [Snet8_x0] [net8_x0] Ksh. This is your weekly savings of [attw8] minus your monthly payment of [x0m] Ksh

Week 9: You would save [attw9] Ksh
Week 10: You would save [attw10] Ksh
Week 11: You would save [attw11] Ksh
Week 12: [Snet12_x0] [net12_x0] Ksh. This is your weekly savings of [attw12] minus your monthly payment of [x0m] Ksh

After 12 weeks, you have paid off your stove, and you can keep all of your weekly savings.

[Show all the savings over all remaining weeks.]

If the price of the Jikokoa is [x0] Ksh would you want to buy it? Select yes or no:

[Note: The Decision Section is repeated 12 times, until the respondent has stated their WTP to the nearest 1 Ksh.]

Confirmation section

[If yes:] So the most you would be willing to pay for the cookstove is [wtp1]?

[If no:] So how much is the most you are willing to pay?

Just to make sure you understand, what happens if the price ends up being [wtp1_p5]?

[If incorrect:] This is not correct! If you are willing to pay [wtp1] and the price turns out to be [wtp1_p5] then you would NOT be able to buy the stove from us! You previously said that you were not willing to pay [wtp1_p5]. Do you understand?

[If incorrect:] This is not correct! If you are willing to pay [wtp1] and the price turns out to be [wtp1_p5] then you SHOULD buy the stove from us for [wtp1_p5] Ksh! Do you understand?

And what happens if the price ends up being [wtp1_m5]?

This is not correct! If you are willing to pay [wtp1] and the price turns out to be [wtp1_m5] then you SHOULD buy the stove from us for [wtp1_m5].

Do you understand?

Just to double check, if the price ends up being [wtp1_p5], would you like to buy the cookstove and pay [wtp1_p5]?

[note: the Confirmation Section can happen up to 4 times. If the respondent still changes their mind or does not understand, the field officer will start again from the beginning]

We have figured out that the maximum amount that you are willing to pay for the cookstove is [finwtp]. We will now open the envelope to see the price. Remember:
- if the price on the envelope is higher than [finwtp], then you will NOT be able to buy the stove today.
- if the price is less than or the same as [finwtp], you SHOULD buy the cookstove today. You will pay the price in the envelope.

Just to make sure you understand, if the price ends up being [finwtp], do you agree to buy the cookstove and pay [finwtp]?

[FO: [If no:] The respondent does not understand! Please repeat the rules again.]

And what happens if the price ends up being [checkFinal]?

[If incorrect:] The respondent does not understand! Please repeat the rules again. If they change their mind, that is okay. Please go back and re-do the BDM BEFORE they open the envelope.

Outcome Section

[FO: Please give the respondent the envelope and ask them to open it and read the price.

The price written in the envelope should say Ksh [hhbdm]. Is this correct?

[FO: [If no:] What is the price written inside the envelope?]

[If lose:]

[FO: DO NOT LET THE HOUSEHOLD PURCHASE THE STOVE]

Unfortunately the price ([price] Ksh) is higher than you are willing to pay ([finwtp] Ksh). You will not be able to purchase the Jikokoa cookstove today. You may still buy a Jikokoa at the regular price of Ksh 2,990 in major supermarkets.

[FO: Did the respondent argue when they found out they could not buy the stove?]

[If win:]

Congratulations! The price is less than you are willing to pay. You may now purchase the stove for [price].