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Gunther Bensch, Jochen Kluve, and Jonathan Stöterau[1]

The Market-Based Dissemination of Modern-Energy Products as a Business Model for Rural Entrepreneurs – Evidence from Kenya

Abstract

This paper provides evidence on a key factor for the success of market-based approaches to disseminate modern-energy products in rural areas of developing countries: the employment and income perspectives of entrepreneurs in the related value chains. We assess the impact of a large-scale energy-access intervention in Kenya that supports individuals in starting a business in improved cookstoves or small solar products. To identify the causal effect of the intervention, the analysis is based on a staggered-implementation evaluation design that takes advantage of sequential roll-out of the programme. The results demonstrate how active entrepreneurs use the new business opportunity to intensify and diversify their income-generating activities, often by shifting away from subsistence farming as a main source of income. This goes along with sizeable improvements in individual and household incomes as well as perceived economic well-being. Impacts significantly differ between the two technologies and across sub-groups, most notably gender. The findings support that market-based approaches can successfully establish sustainable local businesses to foster modern-energy access in rural areas.

JEL Classification: O13, O33, H43, L26

Keywords: Energy-access interventions; cookstoves; pico-solar; value chain; impact evaluation; entrepreneurship training; entropy balancing

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1 *Gunther Bensch, RWI; Jochen Kluve, RWI and Humboldt-Universität zu Berlin; Jonathan Stöterau, RWI and Humboldt-Universität zu Berlin.* *– This paper originates in a research project conducted for the German International Cooperation (GIZ). We are grateful to Anja Rohde, Marlies Kees, and Walter Kipruto for many helpful discussions and comments. The views expressed here are those of the authors only and do not represent the position of GIZ. We further acknowledge the outstanding support of Maja Marcus and the team at the Strathmore Energy Research Centre (SERC) of Strathmore University, Nairobi, in conducting the original research on which this publication is based. We are also thankful to Nico Jersch for excellent research assistance and for helpful feedback at the Berlin Network of Labor Market Research Seminar, the 6th GREThA International Conference on Economic Development and the 2016 Spring Meeting of Young Economists.* *– All correspondence to: Gunther Bensch, RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: bensch@rwi-essen.de*

1. Introduction

Lighting and cooking are the two most essential energy services. Despite their relevance, their availability and usage is confined to traditional types in large parts of the developing world. In rural Sub-Saharan Africa, for instance, 85 per cent of the population lack access to electricity and 83 per cent rely on inefficient traditional stoves or open fire spots to prepare their meals (World Bank/IEA 2015). In order to alleviate these deprivations, international organizations and national governments have promoted the use of improved cookstoves and small-scale solar lighting solutions. Such activities have recently gained momentum with the creation of the global Sustainable Energy For All initiative (SE4All) that envisions universal access to modern energy by 2030.

Many of the initial, subsidy-based dissemination models, however, were criticized by experts for low adoption rates or a lack of sustained demand (Simon et al. 2014). As a response, donor organisations experimented with market-based models to disseminate modern-energy technologies. Recently, SE4All calls for a stronger inclusion of private actors and market mechanisms to achieve its ambitious target (SE4All 2013). One approach is to involve local entrepreneurs in the value chain to ensure demand-driven supply of modern-energy products. This is thought to achieve two ends with a single effort: besides the dissemination of affordable modern-energy technologies, market-based models are supposed to generate non-farm employment opportunities in areas that often struggle with unemployment and a strong dependence on agriculture.

A growing literature is dedicated to demand-side factors related to the adoption of new energy technologies (see, e.g., Malla & Timilsina 2014 or Lewis & Pattanayak 2012 for a review). Yet, the review by Rehfuess et al. (2014) likewise shows that little is known about appropriate and reliable supply chains, which are just as important for successful modern-energy technology dissemination. The authors particularly highlight the challenge to sustain income for entrepreneurs in the value chain in the long run considering seasonality issues and a relatively poor market segment and the seasonality of stove production.

This paper contributes to closing this knowledge gap with first rigorous insights into the employment and income impacts of supporting potential rural entrepreneurs in starting a business in new energy technologies. Specifically, we study a large-scale intervention that provides business start-up and development services related to (a) improved cookstoves and (b) small solar products in rural Kenya. The programme explicitly follows a market-based

approach targeting the long-term sustainable supply of modern-energy products: prospective micro-entrepreneurs are mobilized in their local communities and trained in technological and business skills related to either of these technologies. The intervention places additional emphasis on continuous support for these trained entrepreneurs: following the training, active entrepreneurs gather for regular meetings which serve as a basis for further training, exchange with other actors along the value chain, and reporting of sales figures.

Our identification strategy takes advantage of the continuous implementation of business trainings to compare previously trained entrepreneurs with new training participants. That is, we exploit the staggered programme implementation to generate quasi-experimental treatment and comparison groups in a cross-sectional setting. Since the mobilization and selection mechanism of the programme remained constant across time and regional units, this approach allows us to account for unobservable characteristics which may be related to training participation and thereby minimize bias in our impact estimates.

Between June and August 2015, detailed survey data were collected among 858 entrepreneurs – of which 265 are previously trained, active entrepreneurs (treatment group) and 593 are prospective training participants (comparison group). To account for remaining baseline differences across treatment and comparison groups, we apply a recently developed covariate rebalancing approach, Entropy Balancing (Hainmueller 2012).

Data collection and empirical analysis were guided by labour market factors commonly observed in rural areas of developing countries – namely a strong dependence on incomes from agriculture and a prevalence of multiple job-holding. In particular, we collected detailed data on all income-generating activities to assess the importance of the solar or cookstoves as a primary source of income. This allows testing whether entrepreneurs forego other income-generating opportunities when starting a solar or cookstoves business. Consequently, our main analysis focuses on overall income of active entrepreneurs rather than only earnings from the respective business.

The empirical results show that the intervention had a distinctive impact on the pattern of income generation of entrepreneurs: given that the vast majority of participants already have some source of income at the time of training, the impact on the extensive margin is small. On the intensive margin, however, we observe a significant increase in the overall number of income-generating activities and total hours of work. That is, our impact estimates provide evidence of an increasing diversification and intensification of income-generating activities

among active entrepreneurs in both the solar and stove business. Most importantly, the intervention appears to reduce the reliance on agriculture as a main source of income, although most respondents do not give up farming entirely in favour of the solar or the cookstove business. We thus find evidence that interventions that equally address supply and demand and coherently follow marked-based principles can boost the establishment of market actors deploying modern-energy technologies even in remote areas.

The paper is structured as follows: Section 2 provides a description of the market-based energy intervention as well as background information on labour markets and energy provision in rural Kenya. Section 3 lays out the empirical identification strategy and describes the survey data collected. Impact estimates on a series of employment- and income-related outcomes are presented in section 4. Section 5 concludes.

2. The Intervention and its Context

2.1. The energy sector and labour market in Kenya

Improved cookstoves are not new to Kenya: stove research and development led to the emergence of an improved charcoal cookstove in the 1980s, the Kenyan Ceramic Jiko (KCJ), and several international organisations have been actively disseminating improved cookstoves in rural areas. While people are becoming more aware of the concept and importance of clean cooking, firewood is still the main cooking fuel for more than 80 per cent of households in the country's rural areas (KNBS 2011). Overall, wood provides 70 per cent of Kenya's national energy needs, thereby putting pressure on local forests that already exhibit the lowest coverage rate in the region (7.6 per cent of the country's land surface according to World Bank 2015). With the increasing need to buy firewood, people are further encouraged to use energy-saving stoves. The private sector is becoming more dynamic, and some international companies also manufacture stoves locally (e.g. Burn Manufacturing or Envirofit). Nonetheless, the majority of enterprises across the cookstove and fuels value chain are artisans and micro and small enterprises (MSEs).

Electricity access is a similar challenge in the country. At present, Kenya's electrification rate is 30 per cent at the national level and only 10 per cent in rural areas according to the Kenyan Ministry of Energy and Petroleum (MEP 2015). While the Kenyan government aims to have all villages connected by 2022 and recently initiated a large-scale "Last Mile Connectivity Project", it is questionable whether households will find the means to afford the

costs associated with grid electricity. In rural areas, solar power may provide affordable and sustainable alternatives or at least bridging technologies to grid connections. Again benefiting from a dynamic private sector, Kenya is one of the most developed markets for solar power solutions in Sub-Sahara Africa. The use of solar lighting has increased fourfold from barely 2 per cent in 2009 to 8 per cent in 2013 (Lighting Africa 2016).

The labour market in Kenya displays characteristics similar to those observed in many developing countries (cf. Campbell 2013, Fields 2012, Oya and Pontara 2015). With an abundance of labour and scarcity of human capital, one observes a high degree of informality and vulnerability (e.g. lack of social protection), the predominance of self-employment and low-productivity subsistence farming ("survivalists"). Typically, individuals simultaneously engage in different income-generating activities ("multiple job-holding") to supplement the inadequate and unstable earnings accruing from just one. Youth un- and underemployment is a striking feature of the Kenyan labour market: with merely 32 per cent of youths being employed in 2011, the gap between youth and adult employment rates reached 43 percentage points – one of the largest in Sub-Saharan Africa (Escudero and Mourelo 2014).

These labour market characteristics translate into specific employment situations often encountered in the rural economy: the incidence of off-farm and informal sector work in rural Kenya is high by international standards, not least as compared to other Sub-Saharan African countries (ILO 2013). For example, many individuals are simultaneously engaged in small-scale subsistence farming, seasonal agricultural wage labour and non-farm self-employment. For most households in rural Kenya, however, agricultural activities continue to be the most important source of income (cf. Oya and Pontara 2015; Mathenge and Tschirley 2015). The reliance on agriculture as a main source of income makes many, especially poor households vulnerable to external shocks (e.g. weather) and seasonal fluctuations in demand.

Against this background, enabling poor individuals to start non-agriculture related businesses can be an important step to diversify their sources of income. In particular, rural non-farm employment can provide a source of income to the landless poor and those who are unable to participate in agricultural activities. In addition, these entrepreneurs may create further off-farm employment opportunities for individuals within their business and along the value chain with potential positive net employment effects.

2.2. The intervention: Energising Development Kenya

The energy-access intervention we study is implemented under the umbrella of the global Energising Development (EnDev) programme. EnDev's main goal is to provide poor people in developing countries with sustainable access to modern energy services by establishing self-sustaining local markets for affordable energy technologies (EnDev 2015). The Kenyan EnDev programme (EnDev-K) was established in 2006 and is implemented by the German International Cooperation (GIZ) in cooperation with the Dutch non-profit development organisation SNV. GIZ currently covers 18 of the 47 counties in Kenya and has intervened in another 6 counties until recently, all located in the Western, Central and Lake Victoria region. SNV additionally intervenes in a total of 10 counties, of which 3 are outside the GIZ counties. At the time of the study, the SNV activities were scheduled to run until the end of 2015, those of GIZ until mid-2018.

The EnDev-K programme focuses on two energy technologies: Improved cookstoves and small solar photovoltaic systems (pico-solar). The stove component supports access to modern cooking energy by promoting the sustainable production, marketing, installation and use of improved cooking stoves. Two types of stoves are promoted, the so-called Jiko Kisasa stove and the Rocket stove.[1] This study focusses on the Rocket stove – the main stove type in terms of produced units and supported stove producers – which is a firewood stove that is stationary installed in the customers' kitchen. In 2012, EnDev-K additionally launched a component to promote the use of small solar lighting products (typically one lighting point potentially complemented by a mobile charger or a radio) that have been quality approved by the Lighting Africa Initiative, a joint International Finance Corporation and World Bank programme. The solar component includes training of private retailers and small-scale entrepreneurs in solar technology, business and marketing skills.

The intervention works in the following way: EnDev-K runs three cluster offices on the ground and has a longstanding working relationship with local representatives of the Ministry of Agriculture, so-called home economics officers, whose network extends deep into rural areas of the country. The starting point for mobilization of entrepreneurs are village-level meetings during which EnDev-K sensitizes participants about improved energy technologies. At the same time, the opportunity for an initial training in either stove or solar business is

[1] Details on the Rocket stove technology disseminated in Kenya can be taken from PSDA (2011). For further technical details on improved cookstoves, see for example, Kshirsagar and Kalamkar (2014) or the Appendix of Bensch and Peters (2015).

announced. Together with local home economics officers and community representatives, EnDev-K selects individuals among those who expressed their interest after the meeting. A main criterion is the willingness to become self-employed and invest into the new business. For solar trainings, up-front investments are higher and participants should already possess some non-farm business. During the two- to three-day solar training, participants are taught basics in solar technology and business and marketing skills. Trainees are then connected to local solar distributors that sell Lighting Africa approved products. In the case of cookstove trainings, participants with basic handicraft skills are chosen. In addition, each participant of a Rocket stove training is required to present a list of 20 interested households as initial customers prior to training. The initial stove training involves a two-day group workshop, followed by practical on-site installation training for about half of the 20 initially presented customers. Trainings are free of charge including lunch and, if required, transport and accommodation costs are reimbursed.

In both EnDev-K components, the initial training is part of a more comprehensive set of activities to support the entrepreneurs in establishing sustainable businesses. Firstly, these are consumer-side interventions in the EnDev-K target areas such as awareness creation, promotional activities, and consumer education. Secondly, entrepreneurs are encouraged to participate in regular reporting meetings among entrepreneurs in one area. These meetings serve to monitor sales figures on an individual basis owing to the outcome-oriented character of the programme. Each entrepreneur is requested to provide a list of customers in the previous reporting period, including names and mobile numbers. Furthermore, EnDev-K offers continuing support and occasional follow-up trainings on technical or business skills to the active entrepreneurs who attend these meetings. Stove reporting meetings are held bi-monthly, usually including all entrepreneurs in one ward. Solar entrepreneurs gather every quarter at the county level. Entrepreneurs receive 500 to 800 KSh (0.5 to 0.8 USD) travel allowances by EnDev-K to attend the reporting meetings if they have sold at least ten stoves or pico-solar systems in the previous reporting period.

According to EnDev-K, around 1,600 people participated in the solar trainings of which about 500 are currently involved in the programme and regularly report sales numbers (see also SERC 2014). The number of active stove entrepreneurs is said to fluctuate between 2,500 and 3,800. Based on EnDev-K monitoring data, until June 2015 over 120,000 pico-solar lanterns have been sold by entrepreneurs cooperating with the programme and 1.9 million improved cookstoves were in use by mid-2015.

3. Impact Assessment Approach

3.1. Identification strategy

The aim of our empirical analysis is to estimate the causal impact of the EnDev-K intervention on labour market outcomes at the individual and household level. An experimental evaluation design was not feasible given that the programme was already underway when data collection started. In addition, the specific mechanism to mobilize and identify potential entrepreneurs is considered one of the main advantages of the intervention design. Against this background, the impact on individuals who already self-selected into the programme is considered the policy-relevant parameter. We thus opted for a quasi-experimental evaluation design that takes advantage of the continuous implementation of new business trainings to identify the causal impact of the intervention: this staggered-implementation approach addresses potential selection bias by sampling later cohorts of the programme as the comparison group, given that these were mobilized and selected in the same fashion as earlier cohorts, the treatment group. It thus mimics a randomized phase-in evaluation design in which not the treatment itself is randomized, but rather the order in which individuals receive the treatment.

Treatment in our case refers to the entire intervention. This includes the mobilization and training component of the programme, but also covers the continuous business development services and mentoring provided by EnDev-K. Participants of the training may thus not receive full business support in case they stop attending the follow-up reporting meetings. In fact, monitoring data show that around 60 per cent of programme participants do not continue with the intervention following the initial training stage, making the setting similar to impact evaluation approaches under "partial compliance". In the specific case, the entire group of initial training participants are the underlying treatment population and those who take up the business following the training are the "compliers" (Angrist, Imbens, and Rubin 1996). Our analysis focuses on the Average Treatment Effect on the Treated (ATT) as the treatment effect of interest – namely the impact of the intervention on people who established a solar or stove business after completion of the training – rather than the impact on all training participants (the Intention-To-Treat effect).

We follow the standard notation of the Neyman–Rubin causal model to define the ATT estimator (Rubin 1974). In the case of the quasi-experimental staggered-implementation design, the ATT estimator replaces the unobservable post-intervention outcome Y of compliers in the early-cohort treatment group T had they not taken part in the training

($E[Y(0)|T]$) with the pre-intervention outcomes of compliers in the comparison group ($E[Y(0)|C]$):

$$ATT^* = E[Y(1)|T] - E[Y(0)|C] = E[Y(1)|t = 0, D = 1] - E[Y(0)|t = 1, D = 1], \quad [1]$$

where *D* is an indicator for compliance (i.e. business start-up and reporting following training participation) and *t* refers to earlier (*t*=0) or later (*t*=1) cohorts of the programme. Since we do not observe future compliance status of individuals in the comparison group given that they have only lately been trained, the ATT estimate will be identified as

$$ATT^* = E[Y(1)|t = 1, D = 1] - E[Y(0)|t = 0]. \quad [2]$$

For two main reasons, this ATT may be biased. First, programme roll-out may not be exogenous to potential outcomes of the treatment and comparison group, $cov(t, Y) \neq 0$. For example, trainings might have been conducted in the most promising and thriving areas first. In this case, potential outcomes in the underlying populations would not be comparable, thus creating an upward bias in the earlier cohorts as the treatment group. A second potential source of bias is that business take-up may not be exogenous to potential outcomes, $cov(D, Y) \neq 0$. Entrepreneurs with more business acumen may be more inclined to start a business and be successful with their undertaking, for example.

While we address the first issue of potential differences between earlier and later training sites through a detailed ex-ante selection of survey sites (see section 3.2), we additionally address both issues in our empirical analysis using non-parametric statistical reweighting-approaches in a selection-on-observables framework. Specifically, we employ a recently developed covariate-balancing estimator called "Entropy Balancing" (Hainmueller 2012). Entropy Balancing assigns weights within the comparison group such that pre-specified balancing constraints imposed on the sample moments of the conditioning variables are satisfied. In our cross-sectional setup without pre-intervention data for the treatment group, the conditioning variables have to be carefully selected and we limit the specification to variables that can be reasonably assumed unaffected by the intervention, both on the household and county level (see section 3.3). In contrast to matching estimators, which are commonly employed to increase similarity between treatment and comparison groups, Entropy Balancing has a number of advantages. Most importantly, recent Monte Carlo studies show that Entropy Balancing is more effective in reducing covariate imbalance than conventional methods based on the propensity score (Frölich et al. 2015, Zhao and Percival

2015). For instance, while propensity score methods often can lead to a decrease in balance of some covariates, Entropy Balancing improves balance for all conditioning variables. On a practical matter, it circumvents the potentially arbitrary back-and-forth process of checking covariate balance in conventional matching approaches, since balancing requirements are fulfilled by construction (Hainmueller 2012).

The Entropy Balancing ATT^{EB} estimator is thus a function of the observed covariates *X*:

$$ATT^{\mathrm{EB}} = E[Y(1)|t = 1, D = 1, EB(X) = w] - E[Y(0)|t = 0, EB(X) = w], \quad [3]$$

where *EB(X)* refers to the weights from Entropy Balancing based on the set of conditioning variables *X*. In our empirical analysis, we condition on the first moment of the distribution. Similar to previous applications of Entropy Balancing (e.g. Marcus 2013), we additionally control in an Ordinary Least Squares (OLS) regression setup for all conditioning variables used in the reweighting step. While this does not alter the treatment effect (as it is mean-independent of all conditioning variables after reweighting), the regression-adjustment decreases unexplained variance in the outcome and thus the standard errors of the treatment effect estimates. This is similar to including control variables in randomized experiments. Whether the ATT estimator produces unbiased estimates essentially depends on the quality and relevance of the conditioning variables *X*, i.e. on the extent to which the new training participants resemble active entrepreneurs from the earlier cohorts at the time when the latter joined the programme once observable characteristics are accounted for.

3.2. Data collection

A crucial feature of the survey design was to ensure that comparison group sites are similar to survey sites at which data for already active entrepreneurs were collected. This was addressed in several ways: among all scheduled trainings within the survey period, we selected those implemented in sub-counties with a low previous engagement of EnDev or other donors. This was done in order to conduct the study in a market environment that is comparable to that of the active entrepreneurs at the time of their training. We then selected comparable EnDev-K interventions areas to collect data among active entrepreneurs for the treatment sample. Selection criteria included socio-economic and cultural factors as covered by the 2012 Kenyan County Development Index (cf. CRA 2012) as well as intervention-specific characteristics, e.g. local availability of inputs such as clay.

We further increased our comparison group sample by nine survey sites in sub-counties that were particularly comparable to existing intervention zones. Since no trainings were foreseen in these sub-counties, we conducted meetings of potential entrepreneurs by meticulously replicating the EnDev-K selection mechanism. To this end, experienced extension officers from EnDev-K counties trained extension officers from the additional survey sites in the mobilization and selection of trainees. The comparability of all survey sites was continuously discussed with project stakeholders and local officials. Eventually, the survey was carried out at 44 survey sites located in 19 among the 27 counties in which EnDev-K currently operates (or operated until recently) and in three additional comparison counties. The geographical distribution of these survey counties and main sampling parameters can be taken from Figure A 1 and Table A 1 in the Appendix, respectively.

Table 1: Number of completed interviews

	Interviews			**Survey Sites**	
	Solar	Stoves	Total	Solar	Stoves
Active entrepreneurs (T)	128	137	265	9	9
Comparison Group (C), of which	294	299	593	14	12
New training participants (C-1)	192	191	383	9	8
Additional comparison sample (C-2)	102	108	210	5	4
Total	422	436	858	23	21

Data collection took place in collaboration with a local implementation partner between June and August 2015; thus in a period with medium economic activity in general so that the sampled information can be expected to provide a good average of the year. In total, 858 individuals were interviewed (see Table 1). All sampled entrepreneurs were willing to participate in the interviews, and only four interviews could not be completed. The surveys were carried out during monitoring meetings for active Rocket stove entrepreneurs (T), before or during trainings for new EnDev-K entrepreneurs (C-1), and during the initial meeting among the additional comparison group sample (C-2). Interviews were conducted face-to-face in a private setting to ensure confidentiality and privacy, and typically took 40 to 60 minutes. The questionnaire was in English and interviews were most often conducted in both Swahili and English, with regional languages being occasionally used as well. Data collection was administered using a tablet-based data collection application.

The survey instruments and methodology were developed in consultation with the project stakeholders and the local implementing partners and tested during field pre-tests. The

questionnaire collected detailed information on a broad spectrum of employment- and business-related topics. While questions focused on the primary income source of respondents, the survey was designed to capture all income-generating activities representing the multifaceted nature of income generation. In the design of income-related questions, several measures were taken to enhance reliability of the answers (see Appendix Table A 2). To complement the quantitative data, semi-structured qualitative interviews were conducted with a sub-sample of survey participants as well as local project stakeholders including reporting meeting coordinators, solar and stove trainers, and representatives of the agricultural ministry.

3.3. Sample statistics

Panel A of Table 2 displays summary statistics for the set of socio-demographic and county-level characteristics included as conditioning variables in the Entropy Balancing procedure. The table shows some apparent differences between treatment and comparison groups before rebalancing (see column (5)). While age differences vanish once we account for the elapsed duration since training of treatment entrepreneurs, we particularly observe that the treatment group individuals are slightly better educated than the comparison group. A slightly higher share in the comparison group is unemployed as compared to those in treatment group when they attended the business training. At the same time, we find a similar share of interviewees in both groups have been farmers at the time of training.

Assuming comparability of survey sites and participant mobilization and selection mechanism across cohorts, averages in the comparison group of new trainees should reflect characteristics of the group of initial training participants underlying our treatment sample. As a consequence, the observed differences would reflect changes in the treatment sample composition due to drop out. Specifically, they suggest that unemployed and less educated individuals are more likely to drop out of the intervention. In addition, there is some evidence that women are more likely to remain in the solar component, but less likely to stay in the cookstove component. These results underscore the importance of the balancing procedure in the subsequent impact analysis.

In addition, in panel A of Table 2 we assess whether county characteristics of new and old intervention areas differ despite our efforts of ex-ante stratification. To this end, we make use of the Wealth Index determined from the latest Kenyan Demographic Health Survey (KDHS)

conducted in 2014.[2] In addition, we assess differences in the rural employment rate from the 2009 Kenyan Population and Housing Census (KNBS 2009) and county-level data from the 2015 Human Development Index (UNDP 2015).

Table 2: Descriptive statistics of treatment and comparison groups

	Treatment		Comparison		Difference
	mean	SD	mean	SD	
	(1)	(2)	(3)	(4)	(5)
Panel A: Conditioning variables					
Female, in %	54.3		55.2		-0.9
Age, mean	39.6	10.2	37.4	12.0	2.3***
younger than 25, in %	4.2		17.9		-13.8***
older than 49, in %	17.4		16.9		0.5
Education, in %					
Primary school or less	26.8		34.5		-7.7**
Secondary or vocational	50.9		48.1		2.9
College or university	22.3		17.4		4.8
Main source of income at time of training, in %					
farming	43.0		43.3		-0.3
none	10.6		14.8		-4.3*
Ever married, in %	92.0		78.0		14.0***
Household					
size, mean	5.3	2.3	5.4	2.7	-0.1
single household, in %	4.2		6.1		-1.9
number of children, mean	2.3	1.8	2.4	2.0	-0.0
County-level data					
Wealth Index (KDHS), mean	3.0	0.4	3.0	0.5	-0.0
Cooking with wood (KDHS), in %	85.7		81.1		4.6***
Access to electricity (KDHS), in %	13.9		17.7		-3.8***
Human Development Index, mean	0.5	0.1	0.5	0.1	0.0
Rural Employment Rate, mean	53.1	7.4	53.2	6.3	-0.1
Panel B: Main outcome variables					
Individual is in employment, in %	99.6		85.2		14.5***
Solar / stove business is among income sources, in %	70.2		4.7		65.5***
Personal monthly net income, in KSh	14,331	10,475	9,086	9,935	5,245***
Household weekly food expenditure, in KSh	1,468	870	1,277	841	190***

Notes: Column (5) displays differences between treatment and comparison group before covariate rebalancing. *, ** and *** indicate statistical significance from two-sample mean comparison tests on a level of 10%, 5% and 1%, respectively. Income and expenditure data were collected by 15 intervals. Means were calculated by matching each interval to a weighted average of its bounds; both variables are truncated at the 95th percentile within each business component to account for cases of misreporting. For the income variable, this translates into 55 observations with reported income data above 58,300 KSh (solar) and 43,300 KSh (cookstoves) being omitted from the sample. County-level data sources: KDHS: Own computations based on Demographic Health Survey household-level data using sampling weights (KNBS 2015); Rural Employment Rate: from Kenyan Population and Housing Census 2009 (KNBS 2009); Human Development Index: 2015 Human Development Index (UNDP 2015).

[2] The DHS wealth index is generated via a principal components analysis based on household asset data collected as part of DHS. It has been demonstrated to be consistent with expenditure and income measures (Rutstein and Johnson, 2004). For Kenya-specific details, see KNBS et al. (2015, p. 17ff).

The county-level data provide two important results with regards to the impact analysis: First, we do not detect any significant differences in the composite Wealth Index, HDI and rural employment rate values between counties of treatment and comparison sample. Counties of active stove entrepreneurs are slightly more developed (see Table A 3 in the Appendix); these differences, however, appear economically negligible. Second, the DHS data suggests that treatment counties are somewhat more energy-deprived, with a smaller share of households having access to electricity and a larger share using wood as their primary cooking fuel. This raises the question whether an extension of the programme to these new intervention areas could generate the same impacts as we find for already active entrepreneurs, since the latter have started out in a more favourable market environment. We are able to account for this by including county-level variables in the covariate-balancing procedures.

Panel B of Table 2 provides sample averages for the relevant outcome variables. Prior to the training, about 15 per cent of individuals in the comparison group do not have an employment. Most of them are students or do household work, with a few without occupation. In general, training participants have diverse backgrounds: frequently observed current main income sources among cookstove entrepreneurs are farming and artisanal work such as carpentry. Solar entrepreneurs are more often engaged in trade businesses such as kiosks or street vending. For less than 5 per cent of trainees the business in which they are trained already represented the main income source before the training, e.g. the production of non-improved cookstoves. Our main outcome variable of interest is the reported personal monthly net income from all income sources. Income as well as expenditure data are measured unconditional on working as this can be considered to most closely capture the intervention's intended effect of providing a new source of income. We see a highly significant unconditional difference in the personal net income between active entrepreneurs and the comparison sample, which will be rigorously assessed in the next section.

4. Empirical Results

4.1. Basic profile of the cookstove and solar business

We begin our analysis with basic business characteristics of entrepreneurs active in the two lines of energy-access technologies to better understand potential drivers behind the income and employment effects of the intervention, which we will assess in the following subsections. We further look into the seasonality and volatility of sales in order to gauge whether the supported businesses provide for a regular and predictable source of income. It

becomes apparent that the solar business is a typical product retailing business, whereas the cookstove business may rather be considered product manufacturing. This different nature is, for example, reflected in the businesses structure and workforce (Table 3). Solar entrepreneurs mainly perform their business as own-account workers[3] and often rely on a network of independent resellers. In contrast, two thirds of stove entrepreneurs have had at least one employee in the last three months and many are organized in producer groups. Employment – in particular in the cookstove business – seems to mostly involve temporary, rather low-paid jobs. Finally, solar entrepreneurs more frequently use commercial banking products and borrow money for their business (see asterisks in column (3)). This is likely due to the retail nature of the business and the related larger capital requirements, as well as to higher education (and thus financial literacy) levels of solar entrepreneurs.

Survey respondents were also asked about sales in a typical month, in terms of the number of products sold and total revenue. One observes a considerable positive skew in the distribution of products sold and revenue, meaning that most entrepreneurs report small or moderately large figures, while few entrepreneurs sell a large number of products. Comparing the two types of enterprises, cookstove entrepreneurs sell fewer products and report lower revenues, with a median of roughly 8,000 KSh per month, in contrast to only 20,000 KSh for solar entrepreneurs (80 and 200 USD, respectively). Sales in the solar business are more than double the sales in the cookstove business for each quartile. These differences, however, need to be put in perspective with average mark-up levels. Margins are much higher among cook stove entrepreneurs. Their average mark-up is 232 per cent, which implies that they keep more than two third of what is charged for a stove as profit. This reflects that it is a manufacturing business and labour costs of the entrepreneur are not included in unit costs, whereas the solar business is a mere retail activity. In consequence, average profit levels prove less divergent across both types of business once the difference in mark-up is taken into account.

Table 3: Basic characteristics of solar and cookstoves businesses

	Treatment sample mean (sd)		**Difference**
	Solar	**Cookstoves**	
	(1)	(2)	(3)

[3] According to the "International Classification by Status in Employment", "own-account workers" are workers who hold self-employment jobs (i.e. jobs in which the remuneration is directly dependent upon the profits derived from the goods and services produced) and do not engage any employees on a continuous basis (cf. Campbell 2013).

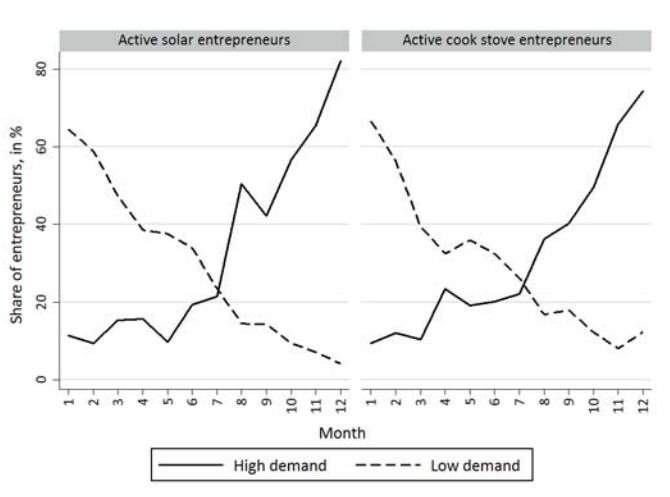
Business performed as, in %			
own-account worker or self-employed	75	85	9.8*
enterprise owner	17	6.6	-11***
employee	9.4	0.0	-9.4***
member of a group or cooperative	7.9	37	29***
Number of employees	0.89	1.7	.82***
	(3.4)	(3.3)	
No employees within last three months, in %	40	64	23***
Type of employees, in %‡			
family members	22	17	-4.9
apprentices	1.8	8.9	7.1**
other permanent	7.9	3.7	-4.2
other temporary	16	44	28***
female employees	52	21	-30***
Weekly pay, in KSh‡#	977	640	-338**
	(820)	(619)	
In-kind payment to any employees, in %	16	3.5	-12**
Resale agents			
no resale agents, in %	52	70	18***
if selling through resale agents…			
number of resellers in total	3.4	1.4	-2***
	(6.9)	(3.2)	
share of sales through resellers, in %	36	39	2.4
	(31)	(32)	
Has separate bank account for their business, in %	48	25	-23***
Ever borrowed money for their business, in %	57	32	-25***
Number of products sold in last month#	19	9.2	-10***
	(16)	(5.8)	
Revenue in an average month, in KSh			
mean#	23,069	10,632	-12,437***
	(14,443)	(9,103)	
lower quartile	10,600	5,000	
middle quartile (median)	20,000	8,000	
upper quartile	30,000	15,000	
Gender of customers is female, in %	67	71	3.5*
Mark-up over input costs, in %†			
mean	32	273	241**
median	27	91	
Average sales ratio between lowest- and highest-sales month, in %	22	22	0.002
	(18)	(17)	
Sample size	118	149	

Notes: ‡ Variable measured conditional on having employees within the last three months. # Variable truncated at the 95th percentile within each business component to account for cases of misreporting. † Mark-ups are computed based on detailed data on reported sales prices of each product type sold and the reported input prices incurred.

Reported demand volatility is sizable: the vast majority of entrepreneurs in both businesses report that sales in the lowest-sales month amount to 50% or less of the sales in the highest-sales month. Figure 1 illustrates fluctuations in demand over the course of the year by

displaying the share of interviewees who report that the respective month was high or low in demand. Qualitative survey responses suggest that demand is decisively influenced by specific events occurring at the turn of the year: regionally relevant cash crops are coffee (harvest between May and June) and tea, for which bonuses are usually paid in November or December. School fees are due in January or February and are mentioned as the single most important factor for low demand periods by entrepreneurs.

Figure 1: Months with high and low demand



Taken together, our data clearly reflect underlying business structures of the two modern-energy technologies. While the stove business is typically performed as a rather low-volume, high-margin manufacturing business, the opposite appears true for the solar retailing business. Furthermore, sales in both businesses seem to be strongly dependent on macro-level factors that drive the overall rural economy, especially farming incomes.

4.2. Business start-up

The starting point of the impact assessment is to analyse to which extent trained entrepreneurs were able to establish their business as an income-generating activity. Table 4 presents corresponding results. The table displays mean outcomes for the Entropy Balancing reweighted comparison group and the corresponding impact estimates from a linear regression on the outcome variable using the weights from the Entropy Balancing procedure

as suggested by Hainmueller (2012). The third column presents the corresponding *t*-test statistic based on robust standard errors.

Table 4: Impacts on income-generating activities and working hours

	Reweighted comparison mean	Impact estimate	
		coefficient	Difference (*t*-statistic)
	(1)	(2)	(3)
Individual is in employment, in %	89	10***	8.41
Business is among income sources, in %	6	92***	66.04
Business is main income source, in %	3	67***	25.60
Number of income sources, mean	1.44	0.98***	15.46
Only one income source, in %	49	-42***	-13.63
Contribution of main income source to personal total net income, mean in %‡	74	-21***	-10.00
if main income source is solar or stoves, mean in %	74	-15***	-6.52
Working hours per week…, mean‡			
in total†	40	10***	4.13
in respective business	1	26***	18.78
Farming activity, in %			
among income sources‡	66	1	0.34
main income source‡	51	-36***	-12.52
regularly sells produce on the market	76	3	0.92

Notes: Comparison group means are reweighted based on Entropy Balancing weights. ‡ conditional on earning an income. † information not available for all entrepreneurs. *, ** and *** indicate that the coefficient is significantly different from zero on a level of 10%, 5% and 1% respectively.

The impact estimates provide several important results regarding the adoption of the cookstove or solar business as an income source among active entrepreneurs: First, we observe that a large share of entrepreneurs regards the cookstove or solar business as their main source of income. Only for few of the training participants, the business was already an income source prior to the training. This can be taken as an indication that the training actually established the businesses as *new* sources of income among entrepreneurs, rather than extending existing ones.

At the same time, active entrepreneurs report roughly one income source more than new training participants. For merely 6 per cent of active entrepreneurs, the respective business is the only income source. In stark contrast to that, about half of income earners in the comparison group rely on one income source only. Likewise, we observe that significantly

more time is spent on income generation. The increase in total working hours, however, is less than the amount of hours which active entrepreneurs report to spend in the respective business. The average entrepreneur works around 26 hours per week on their business, which represents slightly more than half of their total working time. Taken together, these results suggest that the new business often complements existing sources of income rather than fully replacing engagement in other income-generating activities.

Finally, many active entrepreneurs continue their engagement in farming, but the dependence on farming as a main income source declines considerably by almost 70 per cent of the pre-training share. That is, the business training provides individuals with the opportunity to shift from agriculture to selling solar lantern or cookstoves and instead keep farming as a side-activity. This reallocation and diversification of income sources goes along with a reduced importance of the main source of income: entrepreneurs for whom the business is the main income source report that earnings from the solar or stove business represents around 60 percent of his or her total monthly net income. Among the comparison group, the main income source represents almost three quarters of their income.

When disaggregating these results between the two business types, we find a similar pattern for entrepreneurs active in the solar and cookstove business (see Table A 4). The main difference is that the shift in income-generating activities is more pronounced for stove entrepreneurs. This concerns in particular the diversification away from a single source of income, which is often farming for new stove training participants. Cookstove entrepreneurs work less in their new activity and seem generally more reliant on agriculture than solar entrepreneurs – both before and after the intervention. That is, despite a strong shift away from farming as a main income source, many stove entrepreneurs continue their engagement in farming.

Taken together, the analysis provides evidence for a distinctive impact on income generation following the start of a solar or cookstove business – namely a diversification and intensification of income-generating activities: the intervention establishes the respective business as an additional and important source of income, although other activities are typically not forgone. Most importantly, the intervention appears to reduce the dependence on agriculture, although most respondents do not give up farming entirely in favour of the solar or the cookstove business.

4.3. Individual and household income

In this section, we assess whether the adoption of the solar or cookstoves business leads to an increase in reported personal and household-level income variables. The first panel of Table 5 provides impact estimates for the entire group of entrepreneurs in both components, which are disaggregated by business type in the bottom two panels. The pooled estimation results indicate significant income gains for active entrepreneurs. On average, Entropy Balancing impact estimates suggest an increase of 4,000 KSh (40 USD) in total personal net income per month above the reweighted comparison group mean. This is a considerable gain of 38 per cent over the comparison group. In line with this, reported household expenditures are roughly 12 per cent higher in the treatment group. This is a bit less than what would be expected, given that active entrepreneurs report to contribute 65 per cent to household income. One indicative interpretation is that households are able to increase savings and assets following business take-up. These findings go hand in hand with a significant reduction in the share of individuals who report that their household regularly faces difficulties to make ends meet. However, the latter result has to be taken with care due to the risk of courtesy bias among the treatment group.

Looking at the impacts separately for each training component we find significant selection and treatment effect heterogeneity. To start with, cookstove entrepreneurs report significantly lower incomes than solar entrepreneurs before the training. In line with the above results on the shift in income-generating activities, income gains then appear larger among cookstove entrepreneurs in the sample. In fact, the estimated impact on solar entrepreneurs is not statistically significant at the 5 per cent level. Hence, the intervention appears to reduce the initial income gap between solar and stove trainees and thus to be more effective in creating an income among disadvantaged groups. In addition, as cookstove entrepreneurs devote less of their working time to the business than solar entrepreneurs (see section 4.2), the former seem to be able to generate the additional income more efficiently. This also seems to be reflected in household-level expenditure data. Household incomes seem to be less strongly affected – it is even the solar entrepreneurs who report an increase in their contribution to household income. This suggests that heterogeneous intra-household work reallocations take place, but stronger measurement error may also simply play a role in household-level income, which could not be elicited as precisely as the entrepreneurs income. To understand this better, we will delve into further subgroup analysis in the next section.

Table 5: Impacts on individual and household income variables

	Reweighted comparison mean	Impact estimate	
		coefficient	Difference (*t*-statistic)
	(1)	(2)	(3)
Panel A: Pooled sample			
Personal monthly net income, in KSh	10,341	3,991***	4.87
Individual contribution to hh. income, in %	64	3	1.12
Household…			
total monthly expenditure, in KSh	6,793	825**	1.96
weekly food expenditure, in KSh	1,310	158**	2.26
regularly has difficulties making ends meet, in %	61	-20***	-5.39
Panel B: Solar sample			
Personal monthly net income, in KSh	13,938	1,664	1.11
Individual contribution to hh. income, in %	60	9***	2.61
Household…			
total monthly expenditure, in KSh	7,938	821	1.23
weekly food expenditure, in KSh	1,626	26	0.20
regularly has difficulties making ends meet, in %	56	-22***	-3.85
Panel C: Cookstoves sample			
Personal monthly net income, in KSh	7,460	5,737***	5.90
Individual contribution to hh. income, in %	68	-4	-1.25
Household…			
total monthly expenditure, in KSh	5,453	1,033**	2.02
weekly food expenditure, in KSh	1,050	238***	3.27
regularly has difficulties making ends meet, in %	68	-20***	-3.69

Notes: All outcomes are measured unconditional on working and censored at the 95% percentile. Comparison group means are reweighted based on Entropy Balancing weights. Coefficient estimates are obtained from an OLS regression using robust standard errors and including the set of conditioning variables as covariates. *, ** and *** indicate that the coefficient is significantly different from zero on a level of 10%, 5% and 1% respectively.

4.4. Impact by subgroups

A recurrent theme in the literature on entrepreneurship programmes is the substantial heterogeneity in their impact on different groups of participants. This concerns in particular differential impacts by gender, age and education level (Cho and Honorati 2014). Impact heterogeneity for male and female training participants were of main interest to this study, but we also discuss potential differentials by age, education level and for individuals that

were farmers at the time they participated in the solar or stove training. Subgroup-specific impacts were computed by balancing covariates within each subgroup stratum.[4]

Impacts on main employment- and income-related outcomes differ clearly across gender: First, females earn significantly less than their male counterparts in both components before and after training participation (Table 6). In addition, they also contribute less to overall household incomes. Despite this, the reported contribution to household income increases generally more among females within each business type, though the increase in their contribution does not fully correspond to their additional earnings. Second, the subgroup analysis shows that the insignificant impact of the solar component is largely driven by virtually zero impacts on male solar entrepreneurs. For female entrepreneurs, the impact is significant with a magnitude of around 35 per cent over the comparison group mean. Among stove entrepreneurs, both male and female participants observe a strong, significant increase in personal net income. Third, despite larger overall income gains from stove trainings both in absolute and relative terms, the solar component is more effective in closing the (large) initial gender gap: income gains for female solar entrepreneurs are below the impact on male stove entrepreneurs, and hence the stove component actually appears to widen the gender gap within components. Note, however, that male stove training participants appear to start out with income levels below that of female solar trainees.

Regarding the weaker impacts on female vis-à-vis male stove entrepreneurs, the data suggests that active female entrepreneurs are more likely to consider the business their main (and single) income source. At the same time, they report fewer working hours in the stove business than males and report significantly lower sales (9,600 KSh vs. 13,600 KSh per month for males). They are also more likely to work as part of a cooperative or group rather than on their own account. Hence, we suspect that women are more likely to perform the business as a side-activity, next to non-market work such as household chores.

While this is also true for female solar entrepreneurs, differences in outcome variables vis-à-vis male solar entrepreneurs are not as strong and we cannot reject the null hypothesis of zero difference for any of them. Rather, the differential impact across gender may be explained by the counterfactual for male solar entrepreneurs: the group of male solar training

[4] This is comparable to estimating separate models for each sub-group in the context of matching approaches, which has been shown to deliver the most accurate results and best balance (Green and Stuart, 2014). The results proved to be similar in size and significance under alternative approaches (e.g. conditioning on interacted covariates while estimating weights in the pooled sample).

Table 6: Impact estimates by gender

	Male			Female		
	Comparison mean	**Impact estimate**	**Difference (*t*-statistic)**	**Comparison mean**	**Impact estimate**	**Difference (*t*-statistic)**
Solar						
Business is main income source, in %	2	67***	11.34	1	71***	13.79
Only one income source, in %	31	-24***	-3.10	46	-36***	-4.75
Contribution of main income source to personal income, mean in %	64	-14***	-2.96	66	-14**	-2.60
Working hours per week…						
in total	36	15**	2.19	37	8	1.54
in respective business	3	35***	8.95	3	29***	9.74
Farming is main income source, in %	36	-27***	-5.89	40	-36***	-6.96
Individual monthly net income, in KSh	17,714	197	0.08	10,013	3,703**	1.98
Weekly food expenditure, in KSh	1,872	-253	-1.39	1,559	121	0.75
Individual contribution to hh. income	67	9*	1.81	52	11**	2.08
Sample size		212			203	
Cookstoves						
Business is main income source, in %	0	61***	11.22	9	67***	13.19
Only one income source, in %	44	-43***	-6.04	55	-46***	-7.47
Contribution of main income source to personal income, mean in %	77	-28***	-5.54	80	-23***	-6.86
Working hours per week …						
in total	38	2	0.51	26	8***	2.88
in respective business	-0	21***	11.87	2	14***	9.57
Farming is main income source, in %	57	-27***	-3.50	66	-49***	-9.05
Individual monthly net income, in KSh	9,153	7,398***	4.56	6,145	4,298***	3.70
Weekly food expenditure, in KSh	1,109	245	1.64	1,021	214**	2.33
Individual contribution to hh. income	78	-12**	-2.38	59	2	0.36
Sample size		171			262	

Notes: See notes to Table 4 and Table 5.

participants in the comparison group consists of a particularly large share of well-educated, young individuals and fewer farmers as compared to the treatment group. New male solar

training participants thus have a better income-generation situation already before joining the programme, which simply leaves less room for further increases, but also sets a higher bar for taking up further income-generating activities. Starting a solar business is merely one of many viable income-generation options, which seems to make more of these people dropping out of the programme subsequently (which we, however, cannot observe in the given research setup). This does not appear to be true for male stove entrepreneurs, who consist to a larger degree of farmers and lower-educated older individuals.

Table 7 provides further subgroup-specific impact estimates for our main income variable of interest, separately for each technology. The reported subgroups are those that are strong predictors of income levels in the control group.[5] We start by looking at impact heterogeneity by age of survey participants. As for all other subgroups, individuals in the comparison sample of new solar training participants report much higher incomes than new cook stove training participants already before undergoing the intervention. Among solar entrepreneurs, we cannot reject the null of zero effect for any of the age groups. While there is some indication of a negative impact on earnings for older training participant, this finding is not stable across specifications. At the same time, we find significantly larger impacts for older and younger individuals in the cookstove component. As in the case of gender, this result suggests that the stove training is most successful for subgroups which observe lower incomes prior to training participation.

This is also confirmed by our analysis across education levels, even though results are not as clear: looking at results for the stove component, the impact appears stronger for lower-educated individuals. But a Wald-test on the interaction term cannot reject the null hypothesis of equal coefficient estimates across both groups. Similarly, we cannot statistically distinguish treatment effect heterogeneity across groups within the solar sample. This may also be due to the largest level effects across the different subgroup analyses: people with higher education have by far higher incomes even in the absence of the intervention.

Table 7: Subgroup impact estimates on personal monthly net income, in KSh

[5] In contrast to the gender-specific impact analysis, these subgroup analyses were not pre-specified prior to conducting the impact analysis and may be considered more of an exploratory analysis of the data. We thus tested whether our subgroup-specific inference is sensible to multiple hypothesis testing but do not find indications for that.

	Solar				Cookstoves			
	Comparison mean	Impact estimate	Difference (*t*-statistic)	N	Comparison mean	Impact estimate	Difference (*t*-statistic)	N
By age								
younger than 30	12,699	2,236	0.76	128	6,066	4,505***	2.80	86
30-39	15,535	2,481	0.87	108	9,520	3,168	1.41	116
at least 40	15,770	-2,217	-1.16	134	6,606	7,603***	5.42	195
By education								
primary education or less	6,914	2,524	0.94	77	4,534	6,183***	4.82	177
at least secondary education	14,970	1,933	1.14	293	8,988	5,709***	4.14	220
By previous work								
Non-farmer	13,773	3,720**	1.99	247	7,298	5,838***	2.99	179
Farmer	12,719	-951	-0.45	123	7,998	5,247***	4.32	218

Notes: See notes to Table 5.

Finally, further interesting insights can be taken from looking at impacts on individuals whose main income source was or is farming at the time of training participation[6]: farmers in either comparison group do not report significantly lower incomes than non-farmers and the impact of the solar training is large and significant only once we exclude farmers from our sample. These people tend to have businesses already before joining the programme, which seems to help them generate higher profits from the new business.

4.5. Sensitivity analysis

As explained in section 3.2, the data collected for the comparison group combine two sources: participants of newly scheduled EnDev-K trainings and participants of trainings specifically held for the purpose of this study. Even though every effort was made to ensure that the process to select and train the latter closely resembles the typical EnDev-K procedure, participants of genuine EnDev-K trainings may constitute a more adequate comparison group in the framework of the staggered implementation research design. In this section, we test whether the impact estimates are robust if we restrict the comparison group to these new training participants. This effectively reduces the comparison group sample from 593 to 383

[6] Specifically, this analysis compares individuals in the comparison group of training participants whose main income source is farming with existing entrepreneurs who report that their main income source prior to starting the stove business was farming.

individuals. Income estimates are reduced only slightly in magnitude but never in direction, and significance levels are rarely affected (see Table A 5 in the Appendix). One feature to note, however, is that the relative impact on male versus female cookstove entrepreneurs changes, suggesting more comparable impacts across gender.

In an additional robustness check (available on request) we exclude all new training participants from the comparison group who are already active in the respective business, for whom the business is thus not new. This effectively only concerns 43 of the 593 individuals in the comparison group. The change in our impact estimates are marginal and insignificant for all variables. Furthermore, we test whether our results are sensitive towards the inclusion of outliers. As could be expected, changing the censoring level from the 95th to the 99th percentile strongly increases average outcomes in both treatment and comparison groups but not the direction of the treatment effect.

4.6. Additional results: Impacts on subjective indicators of economic well-being and perceived quality of work

In a final step, a number of subjective indicators of perceived economic well-being and quality of the current employment situation are assessed to put the income impact estimates into perspective. To judge the economic well-being of entrepreneurs, respondents were asked how they perceive their current and previous economic situation, choosing from six categories ranging from very good to very bad. In order to account for the subjectivity of such perception questions, survey participants were asked to judge the situation of two fictional persons based on a brief profile in order to see whether there are fundamental differences between interviewees in what is perceived as good or bad. Adjusting the answers by these calibration questions does not alter the overall results.

Results are reported in Table 8 for the full sample of entrepreneurs active in either the cookstove or solar business. Overall, the impact analysis of subjective indicators supports the claim that the intervention improves the economic well-being of its participants. Moreover, the intervention appears to significantly improve the perceived employment quality for its participants. In fact, most active entrepreneurs appear highly satisfied with working conditions in both the cookstove and the solar business. At the same time, no impact on job security is found, which may be related to the strong seasonality in demand and sales discussed in section 4.1. The strong increase in the perceived economic stability, nevertheless, may be taken as support for the observed improved economic resilience at the

individual level through a diversification of income-generating activities. In line with differential impacts on personal and household-level reported incomes, the effects are somewhat more pronounced among cookstove entrepreneurs (not reported in the table). This lends further support to the general impression that the intervention affects cookstove entrepreneurs more strongly than solar entrepreneurs.

Table 8: Impacts on perception of economic well-being and quality of work

	Reweighted comparison mean	Impact estimate	
		Coefficient	Difference (*t*-statistic)
Economic Well-Being			
Perceived economic situation two years ago			
rather good, good or very good	44	7.1*	1.77
bad or very bad	31	-3.8	-1.03
Perceived current economic situation			
rather good, good or very good	76	15***	5.40
bad or very bad	9.8	-7.9***	-4.70
Perceived current economic situation better than two years ago	63	7.7**	2.05
Only entrepreneurs not in business two years ago	65	10*	1.80
Quality of Work			
I am satisfied with working conditions overall.	57	19***	5.08
The safety and health conditions are bad.	46	18***	4.42
I am afraid of losing my job / business in the next 12 month.	17	-4	-1.33
I am well paid for the work I do.	15	3.9	1.31
My work allows me to have a stable economic situation.	50	19***	4.67

Notes: All values refer to the share of respondents in the treatment and (reweighted) comparison group who agree to the specific statement. Agree refers to the statements "agree" or "strongly agree" on a six-point Likert scale. Quality of work indicators conditional on working. Comparison group means are reweighted based on Entropy Balancing weights. *, ** and *** indicate that the coefficient is significantly different from zero on a level of 10%, 5% and 1% respectively.

5. Discussion and Conclusions

This paper provides evidence on a key factor for the successful market-based deployment of modern-energy technologies in energy-deprived rural areas of developing countries: the employment and income perspectives of entrepreneurs in the related value chains. To address this question, we study a large-scale programme that promotes improved cookstoves and small solar products through entrepreneurship support in rural areas of Kenya. The identification strategy exploits the staggered programme implementation to generate quasi-experimental treatment and comparison groups. To account for remaining baseline

differences due to partial compliance, we apply a recently developed covariate re-weighting approach, Entropy Balancing.

Our findings provide evidence that market-based approaches can succeed in supporting prospective entrepreneurs with setting up small-scale businesses in rural areas to deploy modern-energy technologies. Firstly, impact estimates suggest that the intervention had a distinctive impact on the income generation of those entrepreneurs who become involved in either the cookstoves or solar business following the initial business training: many derive a major part of their individual and household-level income from it and appear to shift their main income generation towards the business. At the same time, other activities are not necessarily forgone – most entrepreneurs adopt the business as an additional rather than an alternative income source. In fact, the impact analysis provides evidence for a diversification of income-generating activities among active entrepreneurs, with an increase in the overall number of income-generating activities and total hours of work. In particular, the intervention appears to reduce the reliance on agriculture as a main source of income, although most respondents do not give up farming entirely in favour of the solar or the cookstove business. This effect is particularly pronounced among cookstove entrepreneurs.

In line with this result, we find sizeable impacts on individual-level incomes of active entrepreneurs. Our main impact estimate suggests a strong increase in the monthly individual-level income of 4,000 Kenian Shilling (KSh), representing an increase of 38 per cent over the comparison group outcome. Reported monthly total household expenditure increases by 825 KSh (12 per cent). This goes hand in hand with a significant improvement of subjective economic well-being and perceived quality of work.

In addition, we find significant effect heterogeneity between the two types of trainings and by gender: First, the overall stove component generates larger income impacts than the solar component – both in absolute and relative terms. Second, the gender-specific impact of each component differs: the solar training shows larger impacts on female participants while the opposite is true for stove training component. That is, the programme is successful in reducing the initially large income gap between solar and cookstove entrepreneurs and – at least in the case of solar entrepreneurs – the gender gap within technologies.

At the same time, the groups for which we observe the strongest relative impacts are not necessarily those which adopt the business as a major income source or perform better in their business. For example, males and higher educated individuals in the solar treatment

group report significantly higher sales levels and more hours of work in the business than others, but achieve rather lower net income impacts. Rather, it appears that training participants with better alternative opportunities would be more likely to generate high incomes even without the business opportunity. This result implies that such market-based dissemination programmes may face a trade-off in their targeting: If the main goal is to generate off-farm income opportunities for otherwise disadvantaged groups, focusing mobilisation and participant selection on those with the least alternative opportunities may be a valid strategy. If the main goal is the large-scale dissemination of modern-energy products in rural areas, mobilizing high-skilled individuals may be a better strategy. The latter may go hand in hand in with lower adoption rates since these individuals likely have higher earnings potential in other businesses as well. Achieving the two goals with a single effort may not be easy.

Despite significant impacts on the income of active entrepreneurs and related households, some considerations have to be made regarding a cost-benefit analysis of the programme: Firstly, monitoring data indicate that around 60 per cent of initial training participants do not continue with the intervention by attending regular reporting meetings. While it can hardly be estimated how many of these started a business but simply do not report sales figures, this points towards a notable non-continuation rate among training participants despite the thorough mobilization and selection process. Secondly, the overall net impact on the local labour market may not be as large as individual-level evidence suggests. Given the structure of the local market, some degree of substitution has to be expected, with competitors (e.g. producers of traditional stoves) or entrepreneurs in related value chains (e.g. kerosene vendors) negatively affected.

Nonetheless, our findings suggests that interventions which equally address supply and demand and coherently follow marked-based principles can boost the establishment of market actors deploying modern-energy technologies even in remote areas. With significant impacts on income-generating activities and overall incomes among entrepreneurs active in the solar or improved cookstoves business, it appears that both technologies do provide a relevant and sustainable business opportunity. These results are particularly relevant as similar market-based approaches are likely applicable in other health- or environment-related technologies that require basic technical skills such as water filters.

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Appendix

Table A 1: Main sampling parameters

	Treatment sample (active entrepreneurs)	Comparison sample	
		new training participants (C-1)	additional comparison sample (C-2)
main programme participation condition	active since 2014 or earlier	attending training during the time of data collection	mobilized, but not to be trained before follow-up data collection
survey region	existing GIZ intervention counties comparable to training sites for N2 in terms of socio-economic and cultural factors	GIZ or SNV pull-in counties	counties comparable to survey sites of N2 in which EnDev-K or similar actors do not yet operate
survey site and timing	at monitoring meeting held during data collection period	at start of training conducted during data collection period	special meeting venue
sampling frame	lists of active entrepreneurs in zones where monitoring meetings are held	participant lists of upcoming GIZ or SNV trainings	individuals mobilized based on selection and screening criteria (see text below)
timing of sampling	ad hoc random sampling at monitoring meetings*	ad hoc random sampling based on training participant lists	full sample of mobilized people
envisaged number of interviews per site	up to 20	20 (solar) 25 (stoves)	25 (solar) 30 (stoves)

Notes: Pull-in counties refer to counties, where the GIZ activities are about to start or have started only recently. * It was originally planned to conduct random sampling before monitoring meetings based on lists of active entrepreneurs. However, either the number of participants turned out to be too few for sampling or the lists were not comprehensive so that it was opted for ad hoc sampling during the meetings.

Table A 2: Measures to increase the reliability of self-reported income figures

Measure	Description
Showcards	• The use of specific showcards for income questions, which only ask for intervals and allow people to give their reply in a coded way. Referring to the letter displayed on the showcard allowed the interviewee not to directly disclose his or her income to the interviewer.
Sensitization through key stakeholders	• Strong sensitization of coordinators and mobilizers of the different groups and meetings as well as officials, since they were the key people to gain trust of the individual entrepreneurs.
Training of enumerators	• Specific explanations given during the interviews to reassure interviewees that the information would be treated fully confidentially in order to make them feel at ease.
Corroboration of information	• Corroboration of income information through sales information provided by the interviewees. • Use of the EnDev monitoring data to further corroborate the answers given by entrepreneurs already cooperating with the programme.
Proxy variables	• Use of a wide range of proxies for income such as expenditures and assets/ wealth, both for business and private.

Table A 3: Descriptive statistics of treatment and comparison groups, by business

	Solar					Cookstoves				
	treatment		comparison			treatment		comparison		
	mean	sd	mean	sd	diff.	mean	sd	mean	sd	diff.
Conditioning variables										
Female, in %	53.9	0.5	47.1	0.5	6.8	54.7	0.5	63.2	0.5	-8.5*
Age, mean	37.8	9.9	35.7	11	2.1*	41.4	10	39	11.9	2.3**
younger than 25, in %	7.0	0.3	21.5	0.4	-14.5***	1.5	0.1	14.4	0.4	-12.9***
older than 49, in %	14.1	0.3	14.0	0.3	0.1	20.4	0.4	19.7	0.4	0.7
Education, in %										
Primary school or less	14.8	0.4	21.5	0.4	-6.7*	38	0.5	47.3	0.5	-9.4*
Secondary or vocational	47.7	0.5	51.5	0.5	-3.9	54	0.5	44.6	0.5	9.4*
College or university	37.5	0.5	27.0	0.4	10.5**	8	0.3	8.1	0.3	-0.0
Main source of income at time of training, in %										
farming	32.0	0.5	32.0	0.5	0.1	53.3	0.5	54.5	0.5	-1.2
none	9.4	0.3	12.9	0.3	-3.6	11.7	0.3	16.7	0.4	-5.0
Ever married, in %	89.0	0.3	74.1	0.4	14.9***	94.9	0.2	81.9	0.4	13.0***
Household										
size, mean	5.3	2.5	5.0	2.6	0.3	5.3	2.2	5.7	2.7	-0.4*
single household, in %	3.9	0.2	8.2	0.3	-4.3*	4.4	0.2	4	0.2	0.4
number of children, mean	2.4	1.8	2.1	1.9	0.3	2.2	1.8	2.6	2.1	-0.3*
County-level data										
Wealth Index, mean	3.0	0.4	3.1	0.7	-0.1	3	0.4	2.9	0.3	0.1*
Cooking with wood, in %	85.9	9.3	75.3	31	10.5***	85.6	7.5	86.8	6.1	-1.2*
Access to electricity, in %	11.1	9.2	21.9	28	-10.8***	16.4	11	13.5	7.9	2.9***
Human Development Index, mean	0.5	0.1	0.5	0.1	-0.0	0.5	0	0.5	0	0.0**
Rural Employment Rate, mean	51.0	8.3	52.4	7.0	-1.4	55.1	5.8	53.9	5.6	1.2**
Main outcome variables										
Individual in employment, in %	99.2	0.1	87.1	0.3	12.1***	100	0	83.3	0.4	16.7***
Solar/stove business is among income sources, in %	71.1	0.5	2.4	0.2	68.7***	69.3	0.5	7	0.3	62.3***
Personal monthly income, in KSh	15,602	11130	11,542	11245	4,060***	13197	9761	6728	7812	6,469***
Household weekly food expenditure, in KSh	1,652	1,029	1,519	974	133	1289	634	1036	593	252***
Sample size	128		294		422	137		299		436

Notes: See note to Table 2.

Table A 4: Impacts on income-generating activities and working hours, by business type

	Solar			Cookstoves		
	comparison mean	**impact estimate**	***t*-statistic**	**comparison mean**	**impact estimate**	***t*-statistic**
Individual is in employment, in %	90	9***	4.55	88	12***	6.71
Business is among income sources, in %	4	94***	49.36	5	92***	51.18
Business is main income source, in %	1	70***	18.44	4	66***	18.20
Number of income sources, mean	1.57	0.95***	8.84	1.31	1.02***	15.14
Only one income source, in %	44	-35***	-6.87	53	-47***	-11.64
Contribution of main income source to personal total net income, mean in %	65	-14***	-4.06	80	-26***	-9.72
if main income source is solar or stoves, mean in %	66	-7*	-1.75	80	-21***	-7.47
Working hours per week…, mean						
total	43	13***	3.32	34	10***	2.95
in respective business	0	36***	16.00	1	17***	12.40
Farming activity, in %						
among income sources	51	0	0.09	80	1	0.32
main income source	38	-32***	-9.02	62	-39***	-8.29
regularly sells produce on the market	73	-5	-0.92	77	11***	2.73
Number of observations	292	410		280	433	

Notes: See notes to Table 4.

Table A 5: Selected impact estimates with restricted comparison sample

	Reweighted comparison mean	Impact estimate	
		Coefficient	Difference (-statistic)
Pooled Sample			
Monthly personal total net income, in KSh	10,508	3,824***	4.37
male	13,085	4,108***	2.97
female	8,578	3,411***	3.13
Household expenditure, in KSh			
total monthly expenditure	6,819	799*	1.77
weekly food expenditure	1,375	93	1.15
Solar			
Monthly personal total net income, in KSh	14,001	1,601	1.03
male	17,664	248	0.10
female	9,888	3,829*	1.91
Household expenditure, in KSh			
total monthly expenditure	8,141	618	0.89
weekly food expenditure	1,669	-17	-0.12
Cookstoves			
Monthly personal total net income, in KSh	6,721	6,476***	6.38
male	11,497	5,054***	2.64
female	4,731	5,712***	4.40
Household expenditure, in KSh			
total monthly expenditure	5,588	899	1.44
weekly food expenditure	1,031	258***	2.99

Notes: See notes to Table 5. Other income-related results not presented here – including indicators on income-generating activities presented in section 4.2 – remain comparable as well.

Figure A 1: Location of survey sites