Subsidies, credit constraints and demand for productivity-enhancing technologies

Niccoló F. Meriggi Maarten Voors*

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Abstract

We use a sample of households that were recently connected to electricity in rural Sierra Leone, a low income country, to learn about the productive complementarities in energy access. A core constraint in the uptake of productivity-enhancing technologies for many households is the lack of access to credit. One such energy dependent technology are (smart)phones. Increased access to phones as shown promising impacts on economic activity (through reducing search costs, creating market connections, etc). Using a Becker-Degroot-Marschak (BDM) experiment, we first elicit participants' willingness-to-pay (WTP) for mobile (smart)phones. Participants were then offered the opportunity to buy a mobile smartphone at a either a high or low subsidised price (to overcome immediate credit constraints) as well either a short or longer term repayment plan (to overcome inter-temporal credit constraints). We find that neither credit plan changes average WTP for phones. However, relaxing liquidity constraints through credit plans and price subsidies does significantly increase later mobile phone uptake.

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1. Introduction

A large share of the world's poor does not have access to electricity. Without electrification, many smallholder farmers have few options outside primary agricultural production, keeping rural communities stuck at low levels of development. Universal access to electricity could spark sustained economic growth in developing countries, through time saving technologies and by opening up new markets. However, the development success of electrification critically depends on whether households are able to put increased energy access to productive use. Many people remain credit constrained and have limited access to markets.

There has been a recent boom in investments by governments and donors. Across Sierra Leone, recently close to 100 rural villages have benefited from increased access to electricity through the construction of solar mini-grids. However, most people connected to those grids do not adopt electric assets that can increase their productivity and generate economic welfare. Literature on the direct impact of electrification shows mixed results; some find that increased access to electricity can improve welfare by increasing households' productivity [8, 10], while others do not find any impact [6, 12, 13]. Studies that fail to find any impact of increased access to electricity on relevant social and economic indicators point to limited adoption of productivity-enhancing technologies at the household level [12].

One explanation is that many people are simply too liquidity constrained [16, 20, 17]. Temporary subsidies and access to credit have been tested as solution to release this liquidity constraint, and have been found to increase the adoption of several technologies in the domain of preventive health care, agricultural inputs and practices, energy efficient appliances [9, 4, 2, 3, 14, 18, 16, 5, 11].

To test whether the low adoption of welfare improving electric appliances is due to credit constraints, we conduct a field experiment where we partially lift liquidity constraints by reducing transaction prices in locations that have been recently electrified. We look at the demand for and adoption of a popular energy dependent technology: (smart)phones. Phones are considered as a welfare improving electrified appliance, as phones allow for increased market efficiency through reduced search costs, mobile banking services, lower exposure to risk by strengthening communication among social networks, employment generation from a growing phone communication sector, increased financial inclusion through mobile money and banking, and use of phone calls and text messaging to spread information and platform development projects [1].

The BDM approach is one of the most widespread incentive-compatible procedures to measure the expected utility of respondents for new products [15, 5, 7, 2, 3, 14, 11]. Using a BDM auction mechanism to measure WTP, we study the impact of credit on demand for the smartphones, and then use the random subsidized strike price in the BDM to study the

impact of subsidies the uptake of smartphones.

We randomly assigned respondents to two credit treatments consisting of a short-term repayment plan (2 instalments over 2 months) or a long-term repayment plan (a full year of weekly instalments).

The credit product is expected to increase participants' immediate Ability To Pay and therefore, this is expected to reflect in higher bids during the BDM auctions, as participants in the auction will be able to express their real reservation price without being bounded by their immediate availability of cash be constrained

We find a few impacts of the credit product on WTP. However, we document a strong positive impact of both the credit product and the subsidy on the uptake of smartphones. When the higher subsidy level is combined with the long-term repayment credit scheme, the impact on uptake has a much larger effect than all the other combinations possible. Taken together, these results signal that combining credit products with subsidies can increase the cost-effectiveness of the subsidy stimulating the uptake of a new technology that is welfare improving.

2. Experimental Design

A total of 445 respondents from 10 communities where the mini-girds were built were selected to take part in our experiment, and 435 were completed all the phases of our study.In the 10 selected communities, we targeted households that had a residential connection to the mini-grid. From the population of households connected to the mini-grid through a "residential connection" we sample respondents to be classified as "primary respondents" and pre-specified "replacement respondents" should our primary respondents not be available. We then conduct a baseline survey, and randomly invited 305 respondetns to participate in the BDM auction - though only 293accepted the invitation.

Figure 1: Randomization

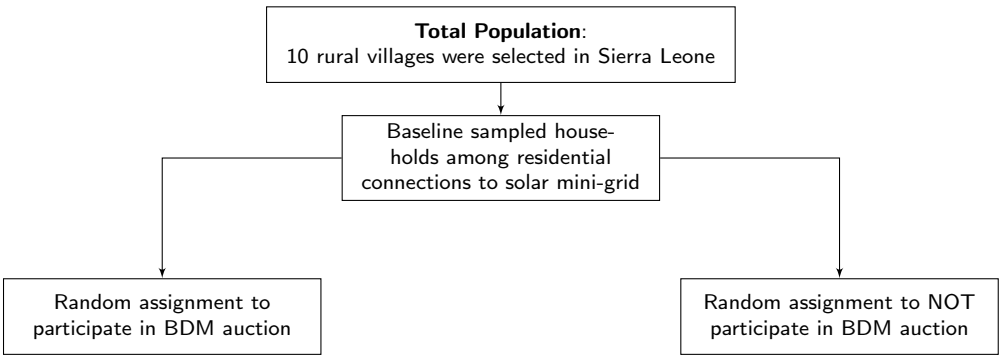


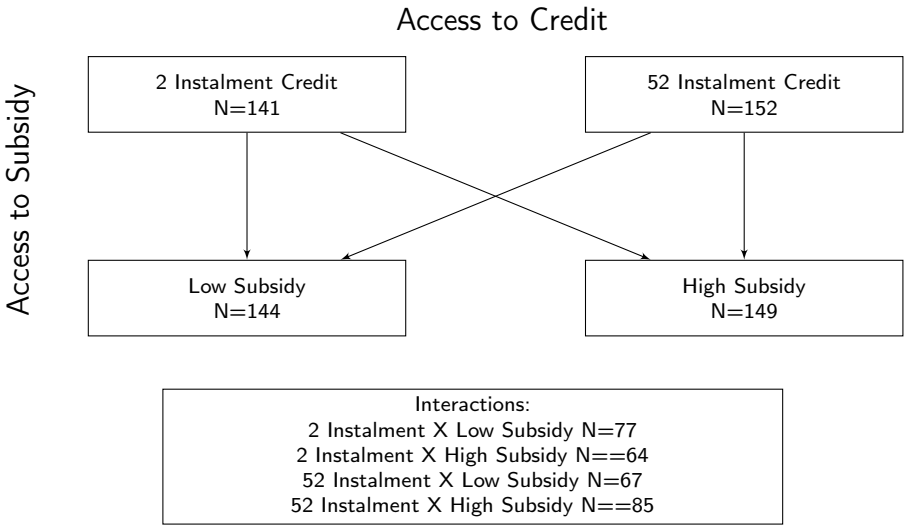
Figure 2 shows the experimental design used to test the following main hypotheses through a 2X2 design:

Hypothesis 1 - Does better access to credit increase the demand for electrified assets?

Hypothesis 2 - Does better access to credit increase the uptake of electrified assets?

Hypothesis 3 - Do price subsidies increase the uptake of electrified assets?

Figure 2: Experimental Design



Before starting the BDM auction, respondents were asked to pick an envelope containing the credit plan they would be subject to as shown in Figure 2. The envelopes contained two different credit plans, one with a shorter repayment period (8-weeks payment plan) and one with a longer repayment period (52-week payment plan). This variation in repayment period exposes participants to different degrees of financial pressure. The 8-weeks repayment plan is considered to be more financially pressing than the 52 weeks repayment period.The credit plans were explained and offered to the respondents before bidding so that the subjects could take this information into account when deciding their maximum WTP for the final good. We hypothesise that respondents' WTP is higher under a longer repayment period because it is not bounded by and conflated with participants' Ability to Pay. This is consistent with prior theoretical and empirical work demonstrating lack of credit access inhibits (lumpy) investments [19].

Following Berkouwer & Dean's (2021), we use a Becker-Degroot-Marschak (BDM) design

to elicit rural households' WTP. Unlike stated WTP approaches, BDM offers an incentive-compatible measure of maximum WTP. When participating in a BDM auction, respondents make individual bids for a commercial item not knowing what the true price is. If their bid is above the strike price, the participant would then receive the goods paying the strike price. If their bid is lower than the strike price, the individual is not allowed to purchase the goods. The phone prices are determined before the beginning of the auction, and unknnown to participants in the BDM. As the prices are unknown and the uptake of the phone is conditional on the respondents' utility stated through their bids in the BDM, it is in the respondents' best interest to report their true WTP.

Before starting the phone auction, we ensured that participants understood the auction process by conducting a practice auction round with "blossom soaps". These soaps are inexpensive and are widely available in provincial Sierra Leone. The practice auction round allowed participants to ask questions about the auction process, clarify misunderstandings and even repeat sections of the auction as needed. Respondents expressed their WTP for the soap in 500 SLL increments. After stating their highest willingness to pay, the respondent selected an envelope containing one of two soap price options: either SLL 3,500 or SLL 2,000. Only after the participant fully understood the BDM soap auction process would the enumerator move on to the BDM phone auction.

When bidding for the smartphone, subjects stated their willingness to pay from a uniform distribution between SLL 100,000 and SLL 1,800,000, in SLL 100,000 increments. In order to assess the impact of a price subsidy on the uptake of smartphone, we exogenously manipulated the prices of the smartphones for each participant. Participants were allocated to two subsidy levels: either one with a 15 percent subsidy (low subsidy) on the market price of the smartphone or a 40 percent subsidy (high subsidy) as seen in Figure 2. If the stated willingness to pay was greater than the randomly drawn price, the participant would then buy the smartphone at the drawn price subsidy. Meriggi et al. (2021) show that subsidies greatly increase uptake, but do not adversely affect subsequent use intensity. Analogous to this study, we hypothesise that short term subsidies effect the uptake of smartphones.

3. Data and Empirical Strategy

We are observing two primary outcomes, where one outcome is respondent's maximum WTP under two different credit conditions i) longer repayment periods and ii) shorter repayment periods. Here we test whether respondents WTP under longer repayment plan would translate into a higher Ability to Pay and consequentially reflected in higher in WTP after releasing the more binding liquidiy constraint. The other outcome is the impact of longer repayment periods, higher subsidies, and the combination of these two on phone

uptake.

Participants were on average about 44 years old, more likely to be male, more likely to be married and have an average household size of 11 people as shown in the summary statistics Table 1 below. Nearly all the respondents reported owning a mobile phone, with about 44 percent of those mobile phones being a smartphone. On average, self-employed respondents made SLL 1,770,000 profits in the past month, and wage-employed respondents made a salary of SLL 2,840,000 in the past month. Those who reported that a member of the household grows crops had about SLL 870,000 of total income from their crops sold in 2021. We further test balance on these variables in Appendix Table 4 in two panels split by the credit scheme and subsidy. Across nearly all dimensions the respondents are comparable, though few differences arise which are presumably due to chance.

Table 1: Auction Sample Summary Stats

	Mean	Std. Dev.	Median	Min.	Max.
HH head is male	0.76	0.43	1	0	1
Age of HH head	44.41	14.14	43	20	105
HH head is married	0.83	0.38	1	0	1
HH head has a disability	0.20	0.40	0	0	1
Household size	10.69	6.26	9	3	43
Owns mobile phone	0.93	0.26	1	0	1
Mobile phone is smart phone	0.44	0.50	0	0	1
Total income from crops (10,000 SLL)	87.45	606.31	0	0	10000
Profits from business in past month (10,000 SLL)	177.19	941.84	34	-350	10970
Cash income in past month (10,000 SLL)	284.35	1449.50	98	3	11500
Asset ownership (land, livestock or electrical appliances)	0.75	0.24	1	0	1
Observations	293				

We estimate the Average Treatment Effect (ATE). All reported effect sizes are through an OLS linear regression on the respondents' maximum WTP against their financial treatment plan. As robustness checks, we use household controls including household size, gender, age, education of the household head and household food expenditures along with village-level controls on population size. We use village-level fixed effects with robust standard errors to account for all unobservable characteristics.

3.1 Attrition

Of the 305 households that were surveyed with the baseline survey and were invited to take part in the BDM auction, 12 individuals did not show up for the auction exercise, leaving the total participants to be 293 people. During the auction exercise, there were 268 participants who bid high enough to be able to purchase the smartphone. Of these 268 there were 227 who purchased the smartphone at the end of the day and 41 who did not end up purchasing

the smartphone due to a lack of cash they had available in their household the day of the auction, resulting in a 15.3% default rate.

4. Results

4.1 Treatment Effect on WTP

The bidding logic to assess a respondents WTP takes into consideration the payment plans (2 instalments or 52 instalments) which are chosen before the respondent bids on the smartphone. In total 20 participants in the 52 week credit plan bid below the strike price and were not offered the opportunity to purchase the phone, and 30 participants allocated to the 2 instalments credit plan did not bid below the strike price. In total there were 50 participants who did not bid high enough for the smartphone, coming to a 17.06% default rate for the 293 participants. There are minor differences between the amounts respondents were willing to pay - those in the 2 instalment credit plan had a range of WTP of SLL 200,000-1,800,000 and a mean of SLL 1,173,050, whereas those with the 52 instalment credit plan had a range of SLL 400,000-1,800,000 with a mean of SLL 1,204,605.

Table 2 below reports the ATE of the payment plan on respondents' WTP. Through various specifications, with and without comprehensive controls (see Columns 1 - 4), we find that respondents who had the 52 instalment credit plan are more likely to express a higher level of WTP for the smartphone. However, these results are not statistically significant.

Table 2: Average Treatment Effect on WTP

	(1)	(2)	(3)	(4)
52 Weeks Plan	31.556	39.473	39.578	34.755
	(37.092)	(35.539)	(35.460)	(35.649)
Household controls	No	Yes	Yes	Yes
Village controls	No	No	Yes	Yes
Village FEs	No	No	No	Yes
Observations	293	293	293	293
Mean in Control	1189.42	1189.42	1189.42	1189.42
Standard Deviation in Control	315.67	315.67	315.67	315.67
R squared	0.00	0.08	0.08	0.14

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figures 3a and 3b show the share of participants who purchased the smartphone varied by the credit treatment that was selected at the beginning of the exercise and the subsidized price level selected after respondents shared their maximum WTP. These are to assess whether access to credit and subsidies encourages the uptake up the smartphone. This is further explained through the demand curve in Figure 4.

Figure 3a: Purchase Decision at Low and High Credit Constraints

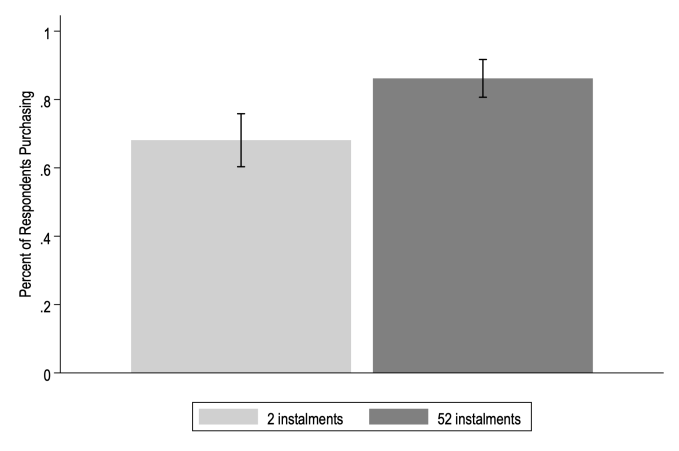


Figure 3b: Purchase Decision at Low and High Subsidies

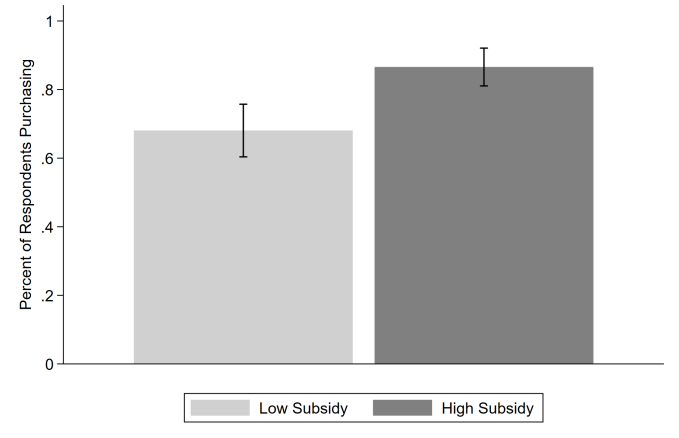
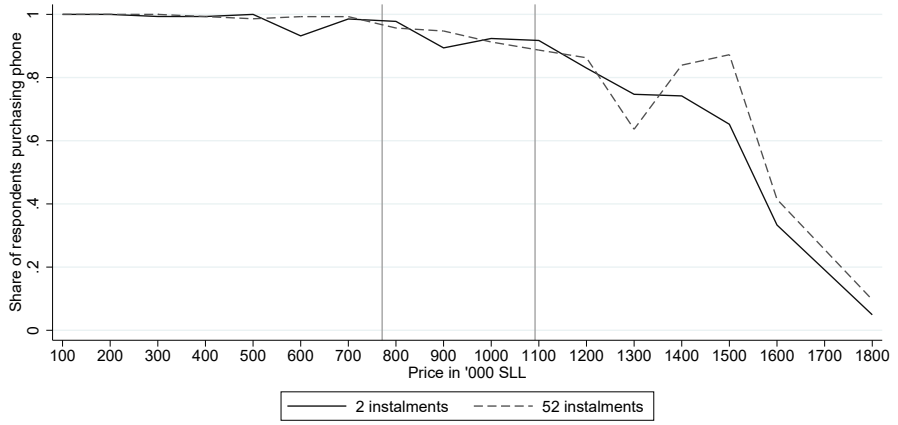


Figure 4 demonstrates the downward-sloping demand curve at different payment plans. There is no evidence of differences in individual responsiveness to different credit plans, nor is there any evidence that at each price point the share of respondents buying (bidding higher than the price) the phone is higher for those offered the 52 instalment credit plan. One plausible explanation could be that the smartphone is a widely known technology. The average market price of these smartphones was reported around SLL 1,417,887 by the sample households before the auction which is close to the actual market price of the smartphone (SLL 1,285,000). This indicates that sample households are aware of the market price of the phone, and are rationally not bidding above such price..

Figure 4: Willingness to Pay by Repayment Plan



4.2 Treatment Effect on Phone Uptake

In Table 3, we test the ATE on phone uptake with and without interactions and robustness checks. Column 1 shows that the 52 instalment credit plan alone boosts phone uptake by 16-17%. These results are statistically significant across various specifications in column 1 - 3 of Panel A without any interactions nor controls. These findings are consistent with prior literature on role of credit in the uptake of merit goods [16].

In Panel B of Table 3 we further test the interaction of price subsidies with credit plans. Our primary specification in column (1) shows that 52 instalment credit plan with higher price subsidy enhances the phone uptake by 29.1% compared to low subsidy and low credit plan. These significant results remain unchanged across all four columns when adding in household and village level controls (column 2 and 3) and using village level fixed effects to control for any unobservables. The effect on phone uptake increases by 30.3% with a better credit and subsidised plan. Overall, these results indicate that credit and subsidies have a

large effect on uptake, whereas credit alone has almost half the effect compared to both the credit and subsidy.

Table 3: Average Treatment Effect on Uptake of the Smartphone

Panel A: Without interaction				
	(1)	(2)	(3)	(4)
52 Weeks Plan	0.173***		0.166***	
	(0.044)		(0.043)	
High Subsidy		0.093**	0.076*	
		(0.045)	(0.043)	
Final phone bid				0.001***
				(0.000)
Observations	268	268	268	268
Mean in Control	.847	.847	.847	.847
Standard Deviation in Control	.361	.361	.361	.361
R squared	0.06	0.02	0.07	0.23
Panel B: With interaction				
	(1)	(2)	(3)	(4)
Low Subsidy × 52 weeks	0.240***	0.244***	0.243***	0.253***
	(0.059)	(0.060)	(0.060)	(0.058)
High Subsidy × 2 Installments	0.227***	0.222***	0.221***	0.226***
	(0.064)	(0.064)	(0.064)	(0.061)
High Subsidy × 52 weeks	0.291***	0.284***	0.287***	0.294***
	(0.058)	(0.058)	(0.058)	(0.056)
Final phone bid	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Household controls	No	Yes	Yes	Yes
Village controls	No	No	Yes	Yes
Village FEs	No	No	No	Yes
Observations	268	268	268	268
Mean in Control	.847	.847	.847	.847
Standard Deviation in Control	.361	.361	.361	.361
R squared	0.33	0.34	0.35	0.41

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusion

This study examines the role of credit and subsidies as policy instruments in the adoption of productivity-enhancing technologies. Using the BDM approach, we assess respondents WTP for the smartphone in rural Sierra Leone where we find that credit alone impacts uptake by 16-17% through relaxed liquidity constraints. Most importantly, credit and subsidy together has a greater impact on smartphone uptake. These results are robust to the inclusion of comprehensive controls and village-level fixed effects.

Future research will look into the complementarities of phone adoption with enhanced electricity access. Here we cannot offer conclusive evidence of factors influencing individual WTP. We can not discount the likelihood of respondents' true WTP being influenced by their knowledge of market prices. More research on productivity-enhancing technology and technology uptake should account for the possibility of anchoring, and additional research is required in these areas.

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6. Appendix

Table 4: Balance Tables

Panel A: Balance table between financial treatments			
	2 Instalments	52 Instalments	(1) vs. (2), p-value
	(1)	(2)	(3)
Respondent female	0.220	0.243	0.580
	(0.035)	(0.035)	
Age	44.882	43.980	0.655
	(1.328)	(1.052)	
Respondent has some education	0.739	0.743	0.935
	(0.038)	(0.036)	
Household size	10.626	10.748	0.887
	(0.528)	(0.532)	
Food expenditures (10,000 SLL)	71.035	87.893	0.160
	(8.224)	(10.580)	
Profits from business in past month (10,000 SLL)	282.136	78.081	0.235
	(161.903)	(21.761)	
Cash income in past month (10,000 SLL)	508.061	100.109	0.346
	(407.270)	(13.741)	
Total income from crops (10,000 SLL)	128.994	48.911	0.246
	(72.727)	(10.359)	
Observations	141	152	
Panel B: Balance table between subsidy treatments			
	Low Subsidy	High Subsidy	(1) vs. (2), p-value
	(1)	(2)	(3)
Respondent female	0.242	0.222	0.695
	(0.035)	(0.035)	
Age	44.048	44.797	0.655
	(1.178)	(1.195)	
Respondent has some education	0.790	0.692	0.059*
	(0.034)	(0.039)	
Household size	10.060	9.500	0.455
	(0.544)	(0.514)	
Food expenditures (10,000 SLL)	90.908	68.265	0.094*
	(10.184)	(8.816)	
Profits from business in past month (10,000 SLL)	112.109	230.444	0.420
	(33.135)	(142.317)	
Cash income in past month (10,000 SLL)	418.322	86.060	0.287
	(308.105)	(10.975)	
Total income from crops (10,000 SLL)	57.752	118.177	0.402
	(17.341)	(69.841)	
Price subsidy	15%	40%	
Observations	149	144	

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$