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Introduction

A “Convivial” World

Ivan Illich (1973:6) describes a world where technological achievements empower the poor and ‘enlarge the range of each person’s competence, control, and initiative, limited only by other individual’s claims to an equal range of power and freedom.’ Illich, alongside Schumacher (1973), envisage a world where technological development is not limited to the improving the quality of life for the privileged, but for all. Though these calls resounded in development literature in the early 1970s, the IMF (2007) reports that technological progress has been a key determinant of widening the rich-poor gap in all regions barring sub-Saharan Africa and the former Soviet Union. Acemoglu (2002:1) first introduced skilled-biased technical change as a possible cause for the inability of the poor to benefit from technological developments and accordingly, the likelihood of an increase in the income gap between rich and poor countries. In addition, a significant amount of literature supports the different rates of technological diffusion in developing countries and developed countries (e.g. World Bank 2008; Hall and Khan 2003; Mulder, de Groot and Hofkes 2003; Mayer 2001). This dissertation will tackle one area of development economics – microcredit – evaluating its track record in empowering the poor, and examining how further integration with technological advancements might help alleviate poverty and build a ‘convivial’ world – as described by Illich.

E.F. Schumacher (1973: 27) makes three requests of scientists and technologists to ensure a better tomorrow: methods and equipment which are;

1. Cheap enough to be accessible to virtually everyone;
2. Suitable for small-scale application; and
3. Compatible with man’s need for creativity.

Humankind has reached a stage where all three points can be addressed while also combating the most important crisis of our time – climate change. Technologies such as solar home systems, solar/biomass cooking stoves, and small-scale wind turbines have the capacity to change millions of lives with renewable energy. These technologies address point number two of Schumacher’s list; they are small-scale and help decentralize ownership. Decentralized technologies allow for the utilization of local knowledge and resources for sustainable and culturally adaptable technological usage. This allows the transfer of power to the public hands whilst building technical skills in the long run. Though the costs of energy generated through these technologies is rapidly decreasing and beginning to rival coal/natural gas based
technologies, see figure 1 in appendix, there remains concern regarding the affordability of these products for those below-poverty-line, defined by the World Bank (2015) as under USD$1.90 a day. This paper will provide a theoretical case for a **shift in emphasis from traditional microcredit to a more asset-based microcredit**, so as to make these technologies available and affordable, thereby addressing Schumacher’s first point.

Traditional microcredit, is defined here as cash-based loans to poor borrowers for income-generating self-employment projects, whereas asset-based microcredit encompasses the dispensation of loans to poor borrowers for specific assets demanded by the poor. These include, but are not limited, to assets such as solar home systems, greater efficiency cooking stoves, education, and mobile phones. Traditional cash-based microcredit focuses on the borrower’s entrepreneurial capability, requiring immediate, efficient investment into current business practices; or inception of *uncertain* business projects, generating profits and paying back the loan. Asset-based loans allow for technological advances (or human capital investment in the case of education) that enable end users to influence existing business and domestic practices to their choosing, saving time and money without unnecessary risk-taking. Importantly, we find that these assets enhance the ‘functionings’ of the individual or household through various, not only income-focused, ways. An asset-based microcredit approach also addresses the time-inconsistency issue, where borrowers gain from the immediate usage of the assets rather than face the uncertain outcome of particular business investments where *optimal decisions* could change over time, but the debt does not. Loan repayment may still be uncertain, but the asset already provides the end user with value from its inception. This not only appeals to the innate short-term thinking of humankind, but also addresses Schumacher’s third point; allowing the user to *creatively* use the asset however they wish to maximise surplus. Due to the scope of the dissertation we will focus specifically on modelling microcredit given for solar home systems (SHS) as it is an exponentially growing industry with vast potential to provide lighting to the 1.3 billion without access to electricity, and the many who live with unreliable electricity connections (Aanesen, Heck and Pinner, 2012 and Walsh, 2013). Around the world largely locally-led organisations have begun to find a market in supplying these technologies to the poor (M-KOPA, Grameen Shakti, Azuri and D.light are a few examples). We shall argue that asset-based microcredit allows for further enlargement of capabilities for poor households.

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1 Education is an asset that does not provide immediate returns, however returns from schooling are widely recognized (Psacharopolous and Patrinos, 2004).
than a entrepreneurship-focused approach necessary for traditional cash-based microcredit which, will be shown, is not always possible or profitable for poor borrowers.

In order to demonstrate the advantages of this approach we must first address two important questions; firstly, have traditional microcredit markets been able to overcome inherent imperfections to provide efficient credit services to the poor, secondly, does access to credit lead to significant poverty alleviation. Section one will give a brief background of microcredit and define poverty as to further shed light on how different perceptions on poverty can influence views on the goals of microcredit. Section two will review the existing theoretical literature around the three major issues in the microcredit market and how current practices attempt to mitigate this. This critique is essential to our discussion as the first step is to tackle the argument that informal microcredit markets are inherently flawed and thus borrowers are unable to benefit from access to credit. We find that, though multifaceted and context based, microcredit organisations have developed ingenious methods of providing functional credit services at interest rates not vastly dissimilar to ones offered through formal credit markets. Section three addresses the subsequent question, does gaining access to credit significantly help poverty alleviation? In order to do so, we review empirical literature – namely the recent randomized controlled trials (RCTs) – that evaluate the impact of traditional microcredit on poverty indicators. Finally, section four proceeds to modelling asset-based microcredit, in particular SHS, to compare it with traditional cash-based microcredit. This paper compares asset-based microcredit with traditional microcredit, without implying that traditional cash-based microcredit is unnecessary. We believe in case-by-case analysis of creditworthiness, but that resources should be diverted from the former to the latter, due to the model’s strengths and especially when the goal is widespread development for the poor. Our discussion will conclude with recommendations for further avenues of research.

Section 1 Background of Microcredit

Microcredit, an idea developed by Muhammad Yunus in 1967 to deliver credit services in Bangladesh to areas without formal financial services, has spread globally as an essential tool for poverty alleviation. The State of the [Microcredit] Campaign Report (2014) shows that as of December 31st 2013, there were 3,098 microfinance institutions (MFIs) lending to 211,119,547 borrowers – the largest number ever recorded. This is approximately a 28-fold

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2 The data excludes smaller MFIs whose combined outreach accounts for around 1 percent of data.
increase from the 7.6 million microcredit recipients in 1997, greatly exceeding the 175 million target for the end of 2015, made at the 2005 Microcredit summit (Microcredit Summit Campaign, 2005 and 2014). This growth reflects the global reaction to microcredit’s perceived success and also shows significant demand from the poor. Microcredit aims to address the poor’s lack of access to bank loans and alleged monopolistic stranglehold that local money lenders are said to have through financial innovation and institutional accountability (Besley and Coate 1995; Morduch 1994; Sengupta and Aubuchon 2008; Banerjee and Duflo 2011). Microcredit organisations unlock a different market than banks because potential borrowers usually do not possess sufficient collateral or bank costs, of screening, monitoring and enforcing contracts, outweigh the profits obtained on the loans. Through individual liability lending or joint liability lending approaches, microcredit organisations attempt to cater to the demand for credit from the poor. Another issue regards the sustainability of microcredit organisations. Due to the substantial number of microcredit lenders that rely on donor subsidies to meet high costs, there is debate between what Robinson (2001) calls, the ‘financial systems approach’ and the ‘poverty lending approach’. The first approach highlights the importance of financial sustainability, whereas the latter emphasises providing credit to help overcome poverty (Hermes and Lensink, 2007). Ultimately, the debate reduces to suggestions that interest rates without subsidies are affordable to the public, or that high interest rates without subsidies could possibly send borrowers into debt traps. This debate is important when we consider that in recent decades, with the introduction of randomized controlled experiments (RCTs), numerous studies have shown the impact of microcredit on poverty alleviation has been grossly exaggerated and, in many cases, actually carries negative effects for borrowers. It is pertinent to identify effects of microcredit, as it influences whether policymakers, NGOs or donors should allocate resources toward subsidizing such microcredit organisations instead of other programmes.

1.2 Poverty Definition

Before proceeding, we must define poverty. There is a particularly important distinction between absolute poverty, a roughly universal and constant standard to which all humans comply, and relative poverty, which Townsend (1985: 36) defines as ‘social exclusion’ that encompasses ‘all of the major spheres of life’, going beyond a subsistent framework. The UN (1995) defined absolute poverty as a ‘condition characterised by severe deprivation of basic human needs, including good, safe drinking water, sanitation facilities, shelter, education and information’, yet the socially-created requirements for all the aforementioned factors implies
poverty must be seen contextually. This relativity is displayed by the differently defined poverty lines in each country, reflecting the comparison to similar purchasing power parity (PPP) levels, and the cost of social inclusion in activities, like weddings or funerals. For our purposes, we will use Amartya Sen’s conciliation of the two in his ‘capabilities’ approach. Sen (1992: 109) defines poverty as the ‘failure of basic capabilities to reach certain minimally acceptable levels’ where life constitutes of ‘doings and beings’ - termed ‘functionings’ - and thus the evaluation of quality of life is the assessment of the capability to function (Sen 1990: 43). This approach helps conceptualize the relevant goal for the credit recipients, which is to widen their set of functionings. This complements Illich’s claim of empowering the poor, as ‘functionings’ is a more specific term for freedom. To further specify our goal, we employ Berlin’s (1956) differentiation between ‘negative’ and ‘positive’ liberties (liberty and freedom here are largely interchangeable); negative liberty being the absence of external constraints, while positive liberty describes the ability to be a master of one’s actions, independent of the constraints of structures and culture. We focus on poverty as an external constraint, restricting the ability to achieve basic capabilities defined by certain minimally acceptable levels thereby viewing poverty as a restricting negative liberty. These minimally acceptable levels clarify that there is an ‘irreducible absolutist core in the idea of poverty’ (Sen 1992: 114). Therefore, it is important to note that income is a means to an end, where the end is the enlargement of capabilities. Our definition further addresses Schumacher’s third point - man’s need for creativity. If poverty alleviation is defined as enlarging capabilities, we give room for how capabilities can be expressed. We shall examine the two models of micro-credit, traditional microcredit and asset-based microcredit, and their ability to augment factors such as self-employment, net income, productive assets, consumption and social impacts such as education and women empowerment.

Section 2: Modelling Traditional Cash-based Microcredit

We will proceed by outlining the theoretical benefits and pitfalls behind traditional microcredit. In doing so, we will create a foundation for subsequent comparison of the viability of asset-based microcredit models. Consequently, we shall look at aspects such as repayment rates, interest rates and social welfare to compare the levels of such factors between traditional cash-based microcredit and asset-based microcredit, as they are implicitly tied with the goal of poverty alleviation. If there is endogenous market failure in microcredit models they will simply not succeed in developing into a legitimate institution, popularity and reach being important precursors for poverty alleviation.
2.1 Theoretical Assumptions Behind the Model

The informal credit market, and related conflict between lenders and debtors, has existed for ‘at least 5,000 years’ (Graeber 2011: 8). The theoretical explanations behind this demand for credit primarily lie with a) the need to smoothen consumption or b) the opportunity to invest in period 1 and obtain profits in period 2. Figure 1 shows how a borrowing constraint restricts consumption in period 1 to point E instead of the ideal scenario of E’, as the former lies on a lower indifference curve.

The aims of microcredit to bring further credit services to the unbanked assumes it is possible to improve the existing services. Informal moneylenders charge ‘usurious interest rates’ because of lacking competition and the arbitrary undervaluation of ‘unmarketable’ collateral (Bhaduri 1977). An alternative, argument suggests that the high interest rates reflect the high risk of lending (Bottomley 1975). Largely disproving the latter argument allowed microcredit to spread rapidly, as repayment rates in early microcredit programmes such as the Grameen Bank were found to be greater than 95%, demonstrating the potential for improvement in the efficiency of informal credit markets (Morduch, 1999). We shall now proceed with listing the assumptions behind our models. We build on the approaches taken by Stiglitz & Weiss (1981), Ghosh & Ray (2001) and Osmani & Mahmud (2015):

1) Borrowers and lenders are risk neutral. ³
2) Borrowers aim to satisfy their participation constraint, earn expected utility greater than 0, \( EU(\cdot) \geq 0 \).

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³ We acknowledge the gravity of this assumption but undertaking analysis with risk-averse individuals would complicate results while not largely altering the conclusions.
3) Lenders aim to satisfy their incentive compatibility constraint and maximise profits. Nonetheless, we assume perfect competition in the markets such that firms all firms maximise profits and earn zero profits, \( \pi = 0 \).  

4) The group of borrowers consist of ‘safe’ and ‘risky’ borrowers; ‘safe’ borrowers have higher probability of success, \( p_s > p_r \). 

5) The probability of success is also a function of the effort borrowers exert, \( p(e) \), with \( p'(e) > 0 \) and \( p''(e) < 0 \). 

6) Expected return to microcredit lenders is a function of interest rate, \( E(r) \), with \( E'(r) > 0 \) and \( E''(r) < 0 \) as after a certain interest rate, safe borrowers drop out of the credit market, leaving only risky borrowers (See appendix 2).

2.2 Joint Liability Lending vs. Individual Lending

Microcredit practices largely use two specific models – individual liability lending (ILL) and the joint liability lending (JLL) models. The former is the standard model in the formal credit sector, where the individual is solely liable for the repayment of loans and usually provides collateral. To combat the lack of collateral in rural areas, the JLL approach creates incentives for members to screen and enforce repayments, thereby reducing costs for the lender. In the case of a loan default, others contribute to ensure repayment and consequent non-repayment by the group, means all group members will be denied future access to loans (Hermes and Lensink, 2007). The idea of collateral through ‘social capital’ employs the information that group members possess of each other and social ties to act as ‘reputational’ enforcement. JLL literature assumes higher repayment rates will eventually create greater welfare for borrowers. This is because higher repayment rates result in decreased interest rates by the microcredit organisations or lender, due to higher profit and a less perceived risk. This lower interest rate benefits borrowers, improving access and rates of future credit.

Several studies have attempted to confirm or reject the hypothesis that socially cohesive groups have higher average repayment rates. Wydick (1999) using evidence from Guatemala shows that social cohesion and group pressure are statistically significant in improving repayment rates. Wydick and Cassar (2010: 737) acknowledge limitations regarding external validity when ‘understanding the relationship between social variables and economic

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4 A strong argument to bring further microcredit services to the poor is simply to generate competition between money lenders, argued to be currently not the case, to drive down interest rates. We shall assume perfect competition to model a fully developed microcredit market with low barriers to entry and simultaneously operating microcredit organisations, driving the interest rates to a socially optimal level.

5 In reality we would assume a continuous spectrum of riskiness associated with individual borrowers, nonetheless to keep our model simple we shall accept a distinction into two groups.
outcomes’. This conclusion that social cohesion helps increase repayment rates in group-lending is also reached by Zeller’s (1998: 618) work in Madagascar, observing the importance of heterogeneity in asset holdings among members, and that diversification among enterprises enables members to pool risks so as to better secure repayment of the loan’. Alternatively, Ahlin and Townsend (2007), using data from Thailand, find (ceteris paribus) a strong negative relationship between the repayment rate and ‘benign social ties’. They conclude the strength of local sanctions rather than social capital is more important for increasing repayment rates. Furthermore, Attanasio et al (2011), in a study in Mongolia, finds no significant difference in repayment rates between two lending programmes, although their approach did not feature weekly group meetings for the JLL programme. It is interesting to note that the Nobel Peace Prize-winning Grameen Bank, the largest microcredit foundation, shifted their largely JLL model to an ILL model that nonetheless still uses compulsory group meetings to generate social cohesion as and direct business discussions (Yunus, 2011). This deviation from both models, labelled implicit joint liability, is shown by de Quidt, Fetzer and Ghatak (2013) to ‘mimic or even improve on the repayment performance and borrower welfare’ of standard JLL models. This has been empirically observed by Gine and Karlan in the Philippines (2011), who found that randomly removing the JLL clause while maintaining group meetings had no significant effect on repayment rates. Perhaps then social cohesion and discussion rather than the JLL approach is the tool for successful microcredit implementation. Nonetheless, this hypothesis regarding the implicit joint liability lending programmes remains untested. This brief review of various studies demonstrates results from the JLL approach, largely stemming from the inability of economists to isolate and measure social variables as an independent variable in their analysis. Furthermore, studies often fail to account for cultural differences, therefore working solely to provide evidence for a case-by-case analysis of the JLL approach. We shall proceed to modelling the two to determine how JLL, alongside other approaches, can mitigate the three problems stated in the individual lending approach – moral hazard, adverse selection and the enforcement problem. After understanding how microcredit remains functional in face of these market perfections, we can address the subsequent question, what are the impacts of cash-based microcredit on poverty alleviation.

2.3 Moral Hazard Problem

Owing to the absence of observation and monitoring, individuals that are given microloans can take actions that negatively affect the probability of repayment – leading to the moral hazard problem. We will use the assumptions listed above alongside building on Osmani
and Mahmud’s (2015) model to show how moral hazards can lead to market failure. Each project taken by ‘safe’ and ‘risky’ borrowers requires a fixed investment, \(I\), which has an uncertain return of \(S\) if it succeeds and 0 if it fails, and takes a cost of effort, \(e\), from the borrower. Therefore expected net return from the project is given by

\[
p(e).S - e - I
\]

If we maximise equation (1), accounting for assumption 2 regarding the borrower’s participation constraint, with respect to effort to find the optimal level of effort \((e^*)\) we get:

\[
max_e: p'(e).S - 1 = 0
\]

\[
p'(e^*) = \frac{1}{S}
\]  

(2)

The optimal effort calculated, \((e^*)\), is most socially beneficial and efficient. Now, we can introduce the loan taken to finance the investment. Let \(R = (1 + r)I\) denote the total repayment amount, where \(r\) is the interest rate and the investment, \(I\), is completely financed by the loan. If there is complete limited liability the borrower would not have to repay the lender in the event of his or her project failing. Some government and donor funded microcredit organisations employ this model, but to make this model as realistic as possible we will introduce \(c\) to signify the borrower’s equivalence of collateral in the event of the inability to finance the loan. For example Harriss-White and Janakarajan (2004) give evidence of utensils and earrings used as collateral in rural India. Following Ghosh et al (2001) we assume that \(c < I\). To get the optimal effort exerted by the borrower we maximise the following equation:

\[
max_e: p(e). (S - R) + (1 - (p(e)).(-c) - e
\]

\[
\text{(Success of project)} \quad \text{(Failure of project)}
\]

Maximising equation (3) w.r.t \(e\) and subject to \(p(e). (S - R) + (1 - (p(e)).(-c) - e > 0\), the agent’s participation constraint, we get

\[
p'(e). (S - R) + p'(e). c - 1
\]

\[
\therefore \quad p'(e) = \frac{1}{S-R+c}
\]

(4)

Equation (4) suggests that the optimal level of effort, \((\hat{e})\), given by \(p'(e)\) is decreasing in \(R\) and increasing in \(c\). This implies that with a higher repayment amount, which is a function of the interest rate, \(r\), the optimal level of effort will decrease. Intuitively this indicates
borrowers who stop trying to repay the lender as the repayment amount increases, because it would cost them too much in terms of effort. It is worth noting that realistically, this outcome may not exist because borrowers stuck in debt-traps can be threatened into worse situations than just losing their collateral, and therefore would not ‘give up’; the Indian government reported that, the last months of 2010 saw the deaths of 80 people due to defaulting on microloans (Biswas, 2010). On the other hand, incentive to avoid losing collateral stimulates a higher optimal effort as \( c \) increases. Because of the widespread microcredit organisation policy to refuse taking collateral from the poor, we should acknowledge \( p'(e) = \frac{1}{S-R} \) in giving optimal values of effort for these situations. Nonetheless, it is argued that social collateral will always be employed to some degree (Postelnicu, Hermes and Szafarz, 2013).

If we compare the optimal level of efforts from equations (2) and (4) we see that \((e^\ast) > (\hat{e})\), provided \( R > c \). If we have a case of extreme limited liability, \( c \approx 0 \), then we get an even greater difference between the socially optimal level of effort from equation (2) and the optimal level of effort when a loan is taken out. This is because the agent is ‘not very keen to raise the level of effort as she knows a part of the fruit of extra effort will be taken away by the lender’ (Osmani and Mahmud, 2015: 12). Thus, the moral hazard problem arises, as ideally the lender would have liked to be able to monitor the agent’s actions, in this case the effort exerted.

On the other side of the contract the lender wishes to maximise his profits, for our purposes we shall assume that assumption 3 holds and the lender makes 0 profit. 

\[
\pi = p(e)R + (1 - p(e))c - I = 0
\]

The lender maximises profits by choosing an interest rate, \( r \), and therefore influencing the repayment amount, \( R \). The repayment amount directly influences the lenders profit levels but the lender must also account for its incentive computability constraint, which gives the effort values, \( e \), of all the borrowers, given values of, \( r \) (and therefore \( R \)). Keeping in mind the perfect competition and non-zero profit supposition (assumption 3), the equilibrium levels of the repayment amount and effort will be given by the intersect between the incentive compatibility curve and the lender’s iso-profit curve (where for all given combinations of effort and repayment amount the lenders profit is the same), shown by figure 4. We can see how the equilibrium \((\hat{R}, \hat{e})\) is not the pareto-efficient outcome, highlighting the moral hazard problem.
Evidently, an important consequence of the moral hazard problem is that the charged interest rate would be higher than the optimal amount, indicated by $\hat{R} > R^*$. If the lender were to reduce interest rates to obtain repayment rates of $R^*$, borrowers would choose an effort level above $\hat{e}$ but below $e^*$ and the lender would then incur negative profits.

It is important, once again, to return to the aspect of collateral. If the lenders are unable to observe effort and if collectable collateral is less than prospective repayment amount, $R > c$, they are restricted to only using rewards to induce effort. The lender is forced to concede some ex ante rent, limited liability rent, to the agent (Laffont and Martimort, 2002: 149). In this scenario the borrower receives expected pay-off $p(\hat{e})(S - \hat{R}) - \hat{e}$ by exploiting the moral hazard condition (Mahmud and Osmani 2015). However, this is costly for the borrower; because the lender has to give up this limited liability rent, they have to raise interest rates in order to compensate, resulting in a sub-paraeto equilibrium with a second-best effort level from the borrowers. We shall now proceed to see how JLL models aim to mitigate these issues.

For our purposes, we will assume a two-person group size with identical preferences and effort functions. Different programmes around the world have different caps on group size. When engaging in JLL models, the Grameen Bank chose to have five members per group, but groups around the world have ranged up to 100 people (Ghatak and Guinnane, 1999: 217). However, studies from Nepal, Ghana and the Dominican Republic suggest that large groups present problems for loan monitoring because of trust issues (Mosley and Dahal 1985; Owusu
and Tetteh, 1982; Devereux and Fishe 1993). Denoting the two individuals as $i$ and $j$, the expected payoff from the JLL approach can be given by:

$$p(\varepsilon_i)(S - R) - p(\varepsilon_i)[1 - p(\varepsilon_j)](c) - e_i \text{ where } i, j \in \{1, 2\}; i \neq j$$

(6)

Since the expected payoff function would be the same for both group members, we can proceed to maximise (6) w.r.t $e$ to obtain the incentive compatibility constraint:

$$p'(\varepsilon)(S - R) - c + 2p(\varepsilon)c = 1$$

(7)

The lender’s profit condition, given it is greater than 0 validating assumption 3, is shown as:

$$\pi = p(\varepsilon)R + p(\varepsilon)[1 - p(\varepsilon)]c - I = 0$$

(8)

To compare the performance of the JLL and ILL approaches, we can substitute the equilibrium values of $R$ to solve for the optimal effort in both cases.

For the ILL approach we rearrange (5), the zero-profit condition of the lender, in terms of $R$:

$$R = \frac{I - c}{p(\varepsilon)} + c$$

(9)

Consequently, substituting in (4), the incentive compatibility constraint for the borrower, to get:

$$p'(\hat{\varepsilon}_{ill}) = \frac{1}{S - \frac{I - c}{p(\varepsilon)}}$$

(10)

Likewise for the JLL approach we rearrange (8), the zero-profit condition of the lender, in terms of $R$:

$$R = \frac{I}{p(\varepsilon)} - [1 - p(\varepsilon)]c$$

(11)

Consequently, substituting (11) in (7) the incentive compatibility constraint for the borrowers, to get:

$$p'(\hat{\varepsilon}_{jll}) = \frac{1}{S - \frac{I}{p(\varepsilon)} + p(\varepsilon)c}$$

(12)

Comparing (10) and (12), the functions of optimal effort for ILL and JLL approaches and assuming $> c$, it can be shown that $\hat{\varepsilon}_{jll} > \hat{\varepsilon}_{ill}$

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6 For the purposes of modelling the JLL approach and its relationship with moral hazard we continue building on the model presented by Osmani and Mahmud (2015).
The JLL model induces greater effort than the ILL model, thereby restricting the limited liability rent given to the agent, lowering the interest rate and mitigating moral hazard. Another advantage of the JLL approach is the diversification effect (Conning, 2005). This suggests that since members undertake various projects, the probability of all of them failing will always be less than the failure of one project. Therefore, the lender, who realises that repayment is more likely, will lower interest rates. As a separate caveat, it is important to note that our conclusions taken from the JLL model rely on strong presumptions, like constant cooperation between members and relatively costless monitoring. We have seen how moral hazard is a crucial problem in obtaining optimal effort and interest rates, and how the JLL approach tackles the problem.

2.4 Adverse Selection Problem

Adverse selection, another form of information asymmetry, can also lead to market failure whereby the market for ‘better’ goods may collapse. This occurs when hidden characteristics render the uninformed side unable to distinguish between groups, thus trade with the wrong party and an unprofitable, inefficient situation. In our scenario this occurs when borrowers know whether they have a ‘risky’ or ‘safe’ project but the lender does not. In the model suggested by Stiglitz-Weis (1981), Arnendariz and Morduch (2005) and Mahmud and Osman (2015), both sets of borrowers have equal expected returns, $p_s R_s = p_r R_r$ where $p$ denotes the probability of success for the two types of borrowers and $R$ the return. The full-fledged function for expected return for both types of borrowers has partially been seen in equation (1) but we also must acknowledge the external factors besides the effort level that is taken into account when determining the return of a project. Examples of these factors are numerous and can be subjective; ranging from the viability of the project to entrepreneurship capability and the impact of exogenous shocks. As such, it is important to remember the difficulties in generating values such as expected return and distinguishing between risky and safe borrowers. Nonetheless, it is in the best interest of microcredit organisations to engage in such calculations on a case-by-case basis to place individuals on a ‘risk’ spectrum. For simplicity’s sake, we have placed these factors into $p_s R_s$ for the expected return of safe borrowers and $p_r R_r$ for risky borrowers. We take risky borrowers to have a higher variance, implying $p_r < p_s$ (assumption 4), and therefore, since we expect equal expected returns, a higher return, $R_r > R_s$. To compensate for the different probabilities of default, lenders would like to charge the ‘risky’ borrowers a higher interest rate to satisfy assumption 3. However, due to the mixture of groups, the lender resorts to calculating an equilibrium pooling interest rate.
relative to the proportion of safe and risky borrowers in the population, \( \mu \) and \( 1 - \mu \) respectively, which ultimately is too high for the safe borrowers and drives them out.

To see this mathematically, building on Mahmud and Osmani’s (2015: 32) model, let us take the common expected return to the two types of borrowers as \( \bar{R} \) and the outside option to borrowers as \( v \).

Rewording assumption 2 we can now state the participation constraints of the two types of borrowers as

\[
\bar{R} - p_s((1 + r)I) \geq v \quad \text{and} \quad \bar{R} - p_r((1 + r)I) \geq v
\]

(13)

Correspondingly, the optimal set of interest rates, if there were a separating equilibrium, would be given by

\[
\bar{R} - v = \frac{p_s}{p_s I} - 1 \quad \text{and} \quad \bar{R} - v = \frac{p_r}{p_r I} - 1
\]

(14)

As \( p_s > p_r \) and we take \( I \) to be the same for both groups, \( r_s^* < r_r^* \).

On the other hand, due to adverse selection the lender will pool the different probabilities of success, \( \bar{p} = \mu p_s + (1 - \mu) p_r \), to determine the interest rate set and satisfy assumption 3, shown by;

\[
\bar{p}((1 + r^*)I) - l = 0
\]

(15)

Where \( l \), is the investment financed by the lender. With further simplification we obtain

\[
r^* = \frac{1}{\bar{p}} - 1 = \frac{1}{\mu p_s + (1 - \mu) p_r} - 1
\]

(16)

We observe that as the proportion of safe borrowers in the population (\( \mu \)) increases, \( r^* \) will decrease as \( p_s > p_r \). It is worth noting that \( r^* \) will always be less than \( r_s^* \) since we assume a certain proportion of safe borrowers. Depending on the outside possibilities and the expected rate of return on the respective projects this leaves us with two possibilities: either \( (r^* < r_s^* < r_s^*) \) or \( (r_s^* < r^* < r_s^*) \) (Mahmud and Osman 2015: 33). The second possibility gives rise to adverse selection whereby safe borrowers drop out of the credit market leading to underinvestment in welfare raising projects and inefficiency.

The JLL approach mitigates adverse selection through supposed assortative matching (Armendariz and Morduch, 2005). This suggests that when borrowers are allowed to pick their own group, since individuals can exploit local information about their peers and projects better
than microcredit organisations, the safe borrowers will come together, leaving the risky borrowers to formulate their own group. This is because it is in the interest of safe borrowers to group with similar types. Since risky borrowers default at a higher rate, they are hurt relatively more by an increase in joint liability than an increase in the interest rate whereas the opposite is true for safe borrowers (Ghatak 2000: 614). This can lead to a situation where risky borrowers drop out of the market, decreasing the interest rate for safe borrowers but not necessarily increasing the total welfare as potentially socially beneficial projects are dropped by risky borrowers. Nonetheless, this self-segregation prompts a chance to offer a separate contract for risky borrowers, perhaps with a higher interest rate but a lower joint liability clause. Another viable option outlined by Batabyal and Beladi (2009) is for safe borrowers to credibly signal to the MFIs. A possible signalling device outlined is the option of self-financing part of the project. If the signal is deemed credible it could result in a separating equilibrium where the safe borrower obtains better terms than a risky borrower. The best possible signal is nevertheless collateral given in place of the loan. As such, safe borrowers are willing to take low interest rate, high collateral contracts rather than risky borrowers. Barboni et al. (2010) conduct games in Bolivia to offer possibilities as to why JLL contracts have fallen in popularity in recent years. They find that when individuals are endowed with a risky project, the percentage of those who prefer JLL contract nearly doubles from 31 - 59%, they continue to show that subjects appear to have motives of free-riding rather than risk diversification. To conclude, the focus on the nature of ‘products’ undertaken by borrowers is clearly a problem for the informal microcredit market as screening and signalling problems can lead to adverse selection. The JLL approach and other viable alternatives has developed to counter this issue.

2.5 Enforcement Problem

A final microcredit market imperfections is the enforcement problem, the ex-post moral hazard. The problem arises when the borrower decides that it is in their best interest to not repay the loan, even when the specific project is successful. This mainly occurs when the lender cannot impose a credible threat to the borrower, because of a lack of collateral or when the collateral is far undervalued when compared to the repayment amount.

We can display this situation mathematically. Since the situation is ex-post, we take a certain monetary outcome from the invested project alongside any personal wealth as $W$, the invested amount as $I$, the collateral posted being $c$, the interest rate $r$, the personal cost of the effort to avoid repayment $e$, and finally probability that the borrower is caught by the lender when deciding to not pay is taken as $\theta$. 

15
Payoff for the borrower after repayment is

\[ W + c - (1 + r)I \]  

(17)

Payoff for the borrower if deciding not to repay is given as

\[(1 - \theta)(W + c) + \theta(W) - e\] 

(18)

The first term signifies when the borrower is able to get away with not repaying and the second term, when he or she is caught and has to give up collateral. The personal cost of escaping detection by the lender occurs in both cases.

In this scenario we can see that in order for lenders to minimise ex-post moral hazard in other words strategic default by borrowers, the following condition must be satisfied.

\[ W + c - (1 + r)I > (1 - \theta)(W + c) + \theta(W) - e \]  

(19)

With simplification we obtain

\[ \frac{\theta c - e}{I} - 1 > r \]  

(20)

Thus, in order for the lender to charge positive interest rates and satisfy assumption 3, the probability of catching the borrower multiplied with the collateral, so when the expected return for the lender when the borrower tries to run without repaying, minus the personal cost to the borrower for trying to escape must be greater than the invested amount, \( I \), shown by \( \theta c - e > I \). This is intuitive, as if the probability of catching the borrower is extremely low or the collateral posted is negligible to the borrower, they will find it in their interest to simply renege on repayment of the loan as the lender poses no credible threat. Therefore, since the lender cannot further punish the borrower, they are limited to only using rewards to incentivise the borrower to repay. However, in this case, conceding limited liability rent by lowering the interest rate will have a certain threshold where lenders will not cross to risk violating assumption 2. As such, there will be a downward impact on volume of loans and therefore a shift from the socially optimal.

The market has a variety of ways to combat the enforcement problem. First and foremost is the ability to cut off access to future credit for the borrower, usually crucial for individuals (Ibtissem and Bouri, 2013). Ironically, if we are assuming perfect competition this widely-used credible threat falls apart as borrowers can resort to other lenders, which points us to how false our initial assumption of perfect competition may actually be if this threat indeed
works. Nonetheless, authors point out that even with other lenders the reputation of a borrower is salient, negatively impacting the borrowing capability of the individual (Mahmud and Osman, 2015: 48, Zhang, 2008). The JLL approach can also mitigate ex post moral hazard. As discussed, the JLL approach allegedly utilizes social collateral and encourages peer monitoring to enforce repayment. In a seminal paper, Beasly and Coate (1995) use a two-stage two-person game-theory analysis where decisions are made simultaneously to find that JLL can be compared both positively and negatively to the ILL approach in enforcing repayment. JLL can have desirable Nash equilibria if there are enough successful borrowers to more than compensate for the amount of unsuccessful borrowers or those who refuse to pay. However, it may be the case that most of the group defaults, leading to a situation where the members who could pay back if not ‘saddled with the weight of liability for their partners’ loans’, choose not to (Beasly and Coate, 1995: 16). The authors advocate social sanctions to raise incentives to repay and help mitigate the negative consequences of the JLL approach. Nonetheless, it is important to note their conclusions about the inconsistencies of all JLL approaches outperforming ILL in terms of repayment rates. Sinn (2009) using similar game-theory analysis looks at sequential group lending, not dissimilar to the style of Rotating Savings and Credit Associations (ROSCAs) which have been used in countries for centuries, to show that there is potential to eliminate strategic default completely. However, it is important to remember that higher repayment rates do not necessarily translate into higher welfare, and sequential group lending could deter riskier projects that are socially beneficial. Clearly, the enforcement problem is a major issue in the informal credit market. The knowledge of being unable to impose a credible threat to the borrower is sufficient to psychologically hinder the potential microcredit organisation to lend, especially when lacking information about the social capital the borrower’s area.

Section 3: Empirical Evidence of Poverty Alleviation: Review of Recent Randomized Controlled Trials

After understanding how the informal microcredit market deals with the aforementioned market imperfections through tools like JLL, we now turn to addressing the crucial premise – access to credit leads to significant poverty alleviation. Banerjee and Duflo (2011) stress that widely evocative personal anecdotes of microcredit lifting individuals out of poverty are not indicative of the vast majority. Randomized Controlled Trials (RCTs) are crucial in removing the guesswork from policy-making by deducing what works and why (Duflo, 2010). The useful aspect of a functional RCT is the ability to isolate the effects of the
treatment, in our case the introduction of microcredit, on exactly comparable individuals or communities as a result of random assignment (see appendix 3). Some of the preliminary empirical panel data studies on the impacts of microcredit, for example Khandker’s (2005: 284) work in Bangladesh, suffers from inherent internal validity issues. Khandker concludes that microcredit helps people in extreme poverty more than those in moderate poverty, but his study is unable to decouple the effects of introducing microcredit and surrounding economic growth, exemplifying one of the issues that can skew results. Nonetheless, we must take the policy implications of RCT’s with a pinch of salt. Though solving internal validity issues, RCTs do not easily resolve external validity issues. A non-representative sample, non-representative treatment (for example due to careful control of programme or the Hawthorne effect on observed individuals) as well as general equilibrium effects, where the effect on the small scale may be different in the large scale, can invalidate the measured effects of treatment. A theoretical example of general equilibrium effects altering results goes as follows; in a cluster of four villages, one is chosen as the ‘treatment’ and is the sole recipient of microcredit. The individuals in the treatment village use the loans to expand their business ventures into the three surrounding villages, showing increased household income results. However if the three other villages are then introduced to microcredit, individuals would find it difficult to continue to expand their business ventures, because a part of the market has been captured by businesses from the first treatment village. This example of ‘crowding out’ is but one reason why we ought to be wary of treating results from RCTs at face value.

Keeping in mind all the caveats associated with RCTs, we will continue to evaluate recent studies in measuring microcredit’s impact on poverty alleviation. We will do so by employing a categorization used in an unpublished paper by Bhargava (2015), which separates poverty alleviation into self-employment and income generating impacts, consumption impacts, and lastly, social impacts like education and women empowerment. This categorization aligns well with our definition of poverty alleviation as an expansion on functionings. We shall use results of six RCTs of microcredit in different countries; Bosnia and Herzegovina by Augsburg et al. (2015), Ethiopia by Desai et al. (2015), India by Banerjee et al. (2015), Mexico by Angelucci et al. (2015), Mongolia by Attanasio et al. (2015) and Morocco by Crépon et al (2015). Key features and results of their RCTs are adapted for the sake of easy comparison and given in table 1.
3.1 Impact on Self-employment and Net Income

Income is one of the most telling indicators of poverty. One would expect the availability of loans to allow for increases in entrepreneurial activity and investment into business ventures leading to higher profit, and consequent repetition until the individual is out of poverty. In terms of entrepreneurial activity, studies in India, Ethiopia, Mexico and Morocco show no statistically significant increase in business creation or ownership. On the other hand, work from Mongolia shows that, in the JLL scheme, access to credit led to a 13% higher probability of entrepreneurial activity, although in the ILL scheme there was no significant positive impact. Finally, the ILL study in Bosnia demonstrates a modest yet significantly positive 6% increase in entrepreneurial activity. It is interesting to note with regards to the study in Mongolia that, the higher performance by the JLL scheme relative to the ILL scheme indicates accordance with theory, where JLL employs social capital to deter non-business uses of loans. Unfortunately, this was the only RCT study that also concurrently compared JLL schemes with ILL schemes. Though the studies in Mongolia and Bosnia revealed modest increases in entrepreneurial activity, we must acknowledge that entrepreneurial activity is a means of increasing income, not an end. Interestingly, the modest increases in self-employment income measured in the Bosnian and Mongolian studies were offset by decreases in wages from external employment income. This suggests that the income effect generated by increases in self-owned businesses allows for reduction in outside labour, indicating that leisure is a normal good and individuals have a higher freedom of choice on how they wish to generate income (Bhargava, 2015). One can argue that the 19 and 14 month time interval between surveys in the Mongolian and Bosnian studies respectively is not sufficient for observing entrepreneurial activity yielding results as an increase in household income. Nonetheless, we must conclude that even though the introduction of microcredit led to increases in business ownership for these two studies, they, alongside the four others, do not show a statistically significant increase in household income. Lastly, the studies in India and Morocco show positive significant effects on income of businesses on the extreme right tail of the business profit distribution, showing that the most profitable businesses gain most from microcredit services. Furthermore, the study in Mexico shows significant negative effects on the left tail, suggesting that the poorest of borrowers stand to lose from borrowing. To conclude, though the vast majority of the studies show a significantly positive increase in purchases of productive assets and two show increases in entrepreneurial activity, none demonstrate a significant increase in income (Banerjee, Karlan and Zinman, 2015: 12). This disappointing result requires further investigation.
This argument for microcredit services lifting the income of the poor relies on two stylized facts; high returns to capital, and latent entrepreneurship skills of the poor. Both these assumptions require in-depth investigation. The diminishing marginal returns to capital theory (see appendix 4) is shown to hold by Mackenzie and Woodruff (2008), who show returns to capital in Mexico for micro-entrepreneurs at about 200% when the market interest rate is about 130%. Crepon et al. (2015) also show in Morocco that returns to capital are close to 140% when the interest rate is about 12.5-14.5%. This indicates a significant profitable scope for borrowers. Nonetheless, the take-up rates in the respective countries are 18.9% and 17%, suggesting the involvement of other factors (Mackenzie and Woodruff 2008, Crepon et al. 2015). This paradox is partially be explained by the fact that marginal returns are high even if overall returns are low (Banerjee and Duflo, 2011) (see appendix 5). This reasoning explains that even if the poor have high marginal returns, because of their small businesses and low profits, they are unable to significantly change their income levels. Take the example of a street vendor in the Philippines selling traditional delicacies to tourists. She obtains a microloan to buy a cart, where she stores food and ingredients. Many others have the same idea, dispersing around the same area to attract customers. As a result of buying the cart she can increase her profits from USD$5 a day to USD$10. Even though a 200% increase is very high, the effect is still not transformational. The decisive factor is in her next step forward. Due to competition she cannot increase her sales drastically, assuming that her delicacies are average compared to other vendors. One risky proposition is that she takes another loan, this one exponentially larger, to open up a restaurant. This runs under the assumption that she can access this loan, as large loans of this degree are often not financed by microcredit organisations, and more importantly that she is willing to take this step. What we have shown is that it may be impossible for some to smoothly rise on the capital-production curve. Taken from Banerjee and Duflo (2011), Figure 5 shows this graphically with OL representing the technologies/business models with lower production capabilities (in the case of our example when the individual still holds the cart) where slow increments of capital will fail to provide a sufficient difference to production. On the other hand, the red S-shaped path indicates the leap necessary to jump on another production frontier. This leap not only requires a big expenditure but true entrepreneurial characteristics such as drive and risk-taking ability. OP represents the select few who manage to transform their small businesses into large-scale ventures, these are the anecdotes employed by the microcredit organisations.
We have seen how the stylized fact of high returns to capital for the poor is not black and white, and that growing a business is difficult. Likewise, we must deconstruct the assumption that the poor are willingly and inherently entrepreneurial. Banerjee and Duflo (2011) through survey work highlight that the poor are forced into running their own small business as a last resort in the absence of a stable job. It is clear that the poor’s primary needs are for a stable position to provide security and basic requirements for themselves and their families. The risk associated with entrepreneurship as well as the debt-burden is often not worth the slim chance of a personal business succeeding. To conclude, we have seen that the RCTs do not find significant impacts on raising income for the poor. This result can be attributed to misplaced claims on the ease of entrepreneurship as well as its demand from the poor.

1.1 Impact on Consumption
Smoothening consumption can temporarily aid individuals who are forced into poverty due to seasonal or exogenous shocks. One robust finding among the RCTs, excluding the study in Ethiopia which did not measure the impact on consumption and the study in Mongolia which failed to deliver conclusive results, is a statistically significant decrease in spending on frivolous goods. We can approach this finding in two ways. Firstly, borrowing for an investment purpose is an end goal for the individual, and they are cautious on how they spend their money. Secondly, fear of falling in a debt trap has forced the family to stop spending money on these goods. There is a subtle difference, as the latter can be argued to negatively affect the freedoms of the individual. On the other hand results on the consumption of durables,
apart from the study in India, fail to show a significant difference. The study in India shows a 17% increase in consumption of durables at the 10% level. This could perhaps be because the study took place in a metropolis where there is a greater set of choices. Banerjee et al. (2015: 48) notes that most commonly purchased durable goods include motorcycles, sarees, gold and silver, TVs, computers, refrigerators and cellphones. However, in general consumption rates are seen to have remained at similar levels before the introduction of microcredit. One can argue that these studies show the effect on the average individual and thus ignore ones that have taken loans to maintain consumption levels due to negative shocks. Nonetheless, we can conclude that consumption levels have not changed in a transformative sense.

1.2 Social Impact

A large part of widening the capabilities of individuals concerns empowering the lives of women and children. There are studies that show evidence of financial control improving the domestic standing of women and that women spend a greater percentage of their income on the welfare of their households than men (Thomas 1990, Duflo 2012). Accordingly, many prompt microcredit organisations to target women as recipients. However, all six RCT’s fail to report increases in shares of children and teenagers attending school. This may be because returns to investments in schooling do not occur in the period that the loan needs to be repaid. As such, borrowers may feel that investment into education will render them unable to generate the necessary repayment amount. Furthermore, enrolment in a year of schooling is often a lump sum cash transfer for fees, investment in this field cannot be accomplished incrementally from returns of business investments. Lastly, apart from the study in Mexico, we do not see statistically significant increases in women decision-making. It is important to take this result with a pinch of salt, as measuring decision-making can be problematic, not highlighting the possibility that even though the women have not become the key decision-makers they may hold more responsibility or have more financial independence. These factors are not measured individually. However, even increases in female decision-making may not result in greater welfare as Angelucci (2008) shows that, in Mexico, women sometimes suffer aggressive behaviour from their husbands after obtaining financial power via microcredit programmes.

After evaluating three essential areas of poverty alleviation, we can conclude that traditional microcredit methods cannot significantly increase the ‘functionings’ of the average borrower. This is primarily because entrepreneurship is difficult and risky. The expectation of the optimization of high-returns in developing countries fails to acknowledge risk-averseness and general equilibrium effects. Yet, traditional microcredit is here to stay, replacing informal
credit lenders, who previously monopolized the industry and failed to provide institutionally led support and legitimacy. Nonetheless we can rule out its heralded transformative effects and can conclude that though measures are being taken to address the three issues, there has been evidence for and against their ability to do so. We now turn to asset-based microcredit as an alternative. Due to the limited scope of the dissertation we focus on energy producing assets, specifically, solar home systems (SHS).

**Section 4: Asset-based Microcredit**

Energy, in all its forms, is pivotal in raising individual standards of living and contributing to economic growth (Indrawati, 2015). There is useful literature that uses the Engel-Granger causality test to find unilateral or bilateral long-run causal relationships between energy consumption and economic growth for developing countries (Oudraogo 2013; Asafu-Adjaye 2000; Kouakou 201; Shahbaz, Khan and Tahir 2013). Biswas, Bryce and Diesendorf (2001) called for the introduction of renewable energy technologies (RETs) to deliver widespread electricity access alongside boosting the quality of life and providing income generating activities for the poor. The false dichotomy previously espoused by energy planners who see ‘the access question as one involving ‘givers’ and ‘takers’: the utility giving electricity or donors giving technology and the consumers taking it’, is starting to break down as the cost of RETs drop and the pressure to battle climate change rises (Sovacool 2012:47). Nonetheless, even with costs now rivalling coal and gas, the high up-front costs and lack of access to finance for the end user are identified as the major obstacles in technological adaptability (Rolffs, Byrne and Ockwell, 2014). Microcredit can be as a solution. The advance of technology has seen the innovative development of real time monitoring using Machine-to-Machine (M2M) technologies and mobile-based microcredit pay-as-you-go (PAYG) finance models that mitigate the three informal credit asymmetries discussed above and also address issues such as high transaction costs between lenders and borrowers (resulting in higher interest rates), unsatisfactory coordination between technology and finance sectors, and lack of accountability. Many of these new business ventures are totally unsubsidized, bottom-up approaches. We shall be modelling the effects of microcredit for SHS by a Kenyan-based company, M-Kopa. They have sold 250,000 SHS’s since October 2012, doubling their revenue to an estimated USD$30 million between 2014 and 2015 (Faris, 2015). This is accomplished whilst simultaneously providing customers with an estimated USD$750 in savings over 4 years, the majority of whom earn less than USD$2 a day (Ibid). Nonetheless, economic modelling still needs to be done to illustrate the advantages over traditional microcredit.
It is worth pausing to consider literature from the field of Science and Technology Studies (STS) that explores the relationship between technology and society. STS findings contribute to an evaluation of how developing societies adopt technology, and how development technology can meet end-user demands increase their set of ‘functionings’ (Krosinsky 2013). Feenberg (2000) argues for a movement from a substantivist ethnocentric view of technology to a more constructivist approach, signifying the necessity of understanding of socio-cultural roots in the uptake and origins of technology rather than a reductionist ‘one-size fits all’ approach. Key here is that technology has the potential to be decontextualized and therefore misused when social and cultural factors are ignored, imposing technological solutions on societies with top-down approaches. For example, the World Bank-funded 4800MW Medupi plant in South Africa has been severely criticized for its future environmental impacts, including severe land degradation, acid rain and greenhouse emissions, and the failure to connect those who are not on the grid (Behrens et al. 2012). We must therefore take a constructivist approach when considering RETs for development. This includes using multi-criteria decision making (MCDM) methods when deciding specific technology usage, like the Analytic Hierarchy Process (AHP) often used when choosing RETs (Kabir and Shihan 2003; Demitras 2013; Singh and Nachtnebel 2016), but also extending democratic local-demand-based principles of technological development on the specific communities. Our scope prevents us from going into further analysis but our support for asset-based microcredit nevertheless depends on these criteria being satisfied. This confirms sufficient uptake and appropriate usage of technologies, sustainably freeing restrictions placed on many of the poor’s negative freedoms and leading to the desired goal poverty alleviation.

4.1 Base Model

Microcredit loan repayment structures for SHS’s are country and package specific, where end-users can pay in different time intervals i.e. daily, weekly or monthly. M-Kopa’s popular loan structure that asks the borrower to pay Kes 2999 (US$35) upfront and 365 daily payments of Kes 40-50 (US$ 0.39-0.49) until the total amount Kes 21750 (US$ 215) is paid. This SHS includes an 8W solar panel, 2 LED light bulbs with cables and switches, 1 LED portable and rechargeable torch, phone charging USB with 5 standard connections, 1 rechargeable radio and a 2 year warranty (M-Kopa, 2016). After 365 daily payments the customer becomes the owner. It is worth noting that the end-user installs the SHS, with assistance over the phone. With the introduction of asset-based microcredit we shift to a household focused approach utility maximisation and cost saving rather than an individual
project based loan model that depends on ‘success’ or ‘failure’ to be able to repay. It is important that we calculate gains and losses through the viewpoint truly model the different effects of SHS on all household members. We shall now outline the assumptions in this model alongside the initial three with similar caveats expressed in section 2.1.

1) Transaction costs for money transfers between borrower and lender and negligible due to mobile payment methods.

2) Household has aggregate production function \( Y(\cdot) \) which can be expressed as \( Ak^\alpha l_n^\beta h_n^\gamma \) where \( A \) is an exogenous efficiency factor which can encompasses technology advancements and entrepreneurial skills, \( k \) is physical capital, \( l \) labour \( (l_n = l_1 + l_1 + \cdots + l_n) \) where \( n \) is the number of household members engaging in household production, the total human capital \( h \) is related to years of schooling, \( s \), according to \( h = s^\mu \) where \( \mu < 1 \).

3) Household members may also engage in salaried labour earning \( w_t \), where \( w \) is the wages earnt and \( t \) the hours worked.

4) There is always a household cost of energy for those not connected to the grid, the widely used alternative in the case of Kenya is kerosene fuels. We denote the average daily cost as \( c_k \) barring an exogenous shock to household production, \( \epsilon \).

5) Households wishing to continue repayments have probability, \( \theta \), of being unable to repay due to the same exogenous production shocks, \( \epsilon \), mentioned in assumption 4.

6) Total repayment amount \((1 + r)R\) decreases as a function of time (in days), due to daily repayments, where \( r \) is the interest rate and \( R \) is the total repayment amount less the initial deposit.

Let us take the representative microcredit-recipient household with utility function \( U_h = U(c, x) \) with \( U_h'(c, x) > 0 \) and \( U_h''(c, x) < 0 \). Where \( c \) is consumption and \( x \) is leisure (in hours). The household’s utility function is defined by a multilinear group utility function, taking into account all household members’, \( n \), utility functions. Theoretical basis for multilinear group utility functions can be found in (Eliashberg and Winkler, 1981). The

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7 We employ a simple Cobb-Douglas function to signify equal elasticity of substitution between inputs, \( \sigma = 1 \).

8 If we consider that quality of education differs between areas and the function of years of schooling is unknown we obtain, \( h = A_h e^{\delta(s)} \), where \( A_h \) denotes quality of education. For simplicity we choose to use a function solely dependent on years of schooling. We take \( \mu < 1 \) consistent with findings by Psacharopolous and Patrinos (2004) in sub-Saharan Africa.

9 This illustrates that households are relatively stable with their household income to pay the daily KES 50, since this is less than the average daily expenditure on kerosene, unless there is an exogenous shock.
household aims to maximise this function w.r.t. three constraints, firstly, each individual household member’s utility functions, secondly, the budget constraint which is the aggregate production of the household and lastly, the leisure time constraint for all individuals. This is of course under the strict assumption that decisions are made at the household level.

\[
\max_{c,x} U_h(c, x) \tag{21}
\]

subject to: \( \sum_{i=1}^{n} c_i x_i, \ c \leq Ak^\alpha l^\beta h^\gamma + wt - (1 + r)R \) and \( x \leq 1 \) for all \( n \).

M-Kopa reports that the average SHS-microcredit recipient household has six people and in 75% of these households the main wage earner is male (M-Kopa, 2015). Using M-Kopa survey results we will see how the introduction of a SHS allows for a multitude of potential benefits and therefore an increase in household utility. Firstly, the stable prospect of solar energy instead of kerosene saves time spent on trips to the market for fuel, while since we can safely assume that kerosene lamps can only illuminate one room, also greatly increasing the accessibility and usage of light for all household members. Take, for example, a street vendor’s family who buys only enough kerosene for one hour a night for the household’s chores. SHS allows them to lift this rationing constraint. The shop vendor now has the option to keep his shop open for the night, whilst other household members can work on their chores. This principle applies to all jobs done from home such as dressmaking, handicraft work or preparing food. Interestingly, 89% of M-Kopa SHS users note that their children study up to 2 hours more per day (M-Kopa 2015), showing how lack of light can severely constrain schoolwork. Children can boost their interest in education as well as their capabilities, human capital \( h = s^H \). M-Kopa survey (2015) also notes that the prime beneficiaries of the SHS are women, potentially increasing their leisure or labour time. As labour, \( l \), increases domestic production increases as a result. Lastly, a result of widespread SHS usage reports also show a significant number of SHS households earning money by leasing their mobile charging units to those in the vicinity who are unable to charge them (M-Kopa 2015). This unanticipated utilisation shows the contextual necessity of technological impact analysis. With these varied hypotheses our minimum conjecture is that domestic production after SHS introduction, \( Y_a \), is at least as much as before, \( Y_b \). In other words, \( Y_a \geq Y_b \), and both are functions of \( Ak^\alpha l^\beta h^\gamma \). Any potential time saved through SHS usage can also potentially increase time, \( t \), engaged in salaried work, \( wt \), further boosting the household’s budget constraint.
Lastly, 99% of SHS-microcredit households save money on kerosene by using SHS (M-Kopa 2015). After appropriate fieldwork M-Kopa found that the average daily cost per household on kerosene is around KES 60, therefore their repayment scheme factored into account savings that could be made for the borrower (Rolffs, Byrne and Ockwell, 2014). This not only appeals to the borrower but ensures high uptake from consumers for the lender. Implying that $Rr \leq c_k$, where $Rr$ is the daily micro-repayments and $c_k$ is the intervallic equivalent cost of kerosene. Borrowers who might not realise the immediate increase in household production stand to gain simply through the potential savings they can earn in the long run. We can also observe the advantages of negligible transaction costs for both parties. The small daily repayments do not burden the borrower with debt whilst at the same time this rewards are made instantaneous by M2M technology can be seen as advantageous for the borrower from a temporal discounting standpoint. If payments were made on a monthly basis the borrower may discount the future value of energy such that the required repayment amount may exceed his or her valuation. Daily payment obligations lessen the size of the discounting factor for the borrower. Even if household production does not increase after the introduction of SHS, utility might increase in the long-run since before the addition of SHS the household budget constraint was $c \leq Ak^aB^bH^c + \omega t - c_k$ and $Rr \leq c_k$.

Nonetheless, potential difficulties arising from the SHS-microcredit must not be neglected. The first major issue, taking the M-Kopa model, is the high upfront cost of KES 2,999 (USD$35) to obtain the SHS. If we take consumers earn less than USD$2 a day, this is equivalent to almost 20 days income. Some customers may not have this much in savings, or might not want to risk such an amount in perceived uncertain technology. M-Kopa approaches the latter case of risk-aversion through guaranteeing a two-year warrantee alongside a reputable 24/7 customer service to address any issues. However, it is clear that as a tool for poverty alleviation M-Kopa’s business model still limits access for people in extreme poverty who are unable to afford the upfront cost. Here there is scope for government and donor-led subsidies to improve affordability.

4.2 Mitigating Moral Hazard Problem

As discussed, the moral hazard problem arises when, due to lack of monitoring, individuals can take actions to negatively affect the repayment of the loan. The key difference between SHS-based microcredit is that loan repayment is tied into immediate returns and thus repayment incentives are already greater than in cash-based microcredit. Furthermore, repayment is no longer based on ‘project’ success, but rather the daily aggregate production of
the household. Since the latter has a more stable property due to essential consumption as well as evidence of the ability to pay for previous, more expensive, sources of energy, unobserved risks of repayment are significantly less than the cash-based microcredit scenario. Even if one argues that aggregate household production is still a function of effort, we can adapt equation (4) to show that

\[ p'(e) = \frac{1}{Y-R+c} \]

The important difference is that \( c > R \), where \( c \) is the collateral and \( R \) is the repayment amount. incentivises the end user to pay the lender back. We see here that individuals and households do not have any incentive to negatively affect the repayment of the loan.

4.3 Mitigating Adverse Selection Problem

Adverse selection arises when the lender is unable to distinguish between risky or safe borrowers due to hidden characteristics. As we have mentioned a potential hindrance to the larger uptake of SHS-based microcredit schemes is the large upfront deposit that must be paid, however this form of signalling to the lender may show the willingness and the ability to pay the smaller daily costs. It is essentially a form of self-financing that Batabyal and Beladi (2009) recommend in order to tackle adverse selection. Interestingly, future adverse selection can also be addressed. M-Kopa has given individuals, who have managed to full repay the SHS microloan, a creditworthy reputation for future borrowing. If M-Kopa’s endorsements become reputable or they develop links microcredit organisations this vetting process through past credit scores can be another signal for microcredit organisation to distinguish between safe or risky individuals. Furthermore, the ownership of the SHS after successful repayment can be used as collateral for future borrowing. To summarize, adverse selection can be mitigated through the upfront deposit, but at the cost of reducing the uptake of SHS-based microcredit. On the other hand future adverse selection can be avoided through credit history signalling and the ability to use the SHS as collateral.

4.4 Mitigating Enforcement Problem

The enforcement problem is most easily countered by M2M monitoring which allows the lender to impose a certain credible threat on the borrower. Quite simply, if the borrower fails to repay, the SHS is disconnected with negligible effort for the lender so the collateral is lost. Another difference is that the borrower requires no effort to ‘escape’ from payment. We define aggregate household production with presence of the collateral (SHS), when there is repayment, as \( Y_R \) and aggregate household production without presence of the collateral, when the
borrower fails to repay, as $Y_{NR}$. This is done to take into account the aforementioned potential differences in production due to the SHS. Using the same logic as in equation as (17).

Payoff for the borrower after repayment is

$$ Y_R + c - (1 + r)R $$

(22)

Where $(1 + r)R$ is the total repayment amount left after a certain point in time (assumption 9). This suggests that as time increases the borrower should be less likely to consider non-repayment by choice.

Payoff for the borrower if deciding not to repay is given as

$$ Y_{NR} - c_k $$

(23)

Where $Y_{NR}$ may be less than $Y_R$ due to aforementioned factors and due to assumption 8 the household still pays for alternative energy sources, $c_k$.

Following the same steps in section 2.5 we can see that for lenders to minimise ex-post moral hazard, or strategic default by borrowers, the following condition must be satisfied.

$$ Y_R + c - (1 + r)R > Y_{NR} - c_k $$

(24)

With simplification we obtain

$$ \frac{(Y_R-Y_{NR})+c+c_k}{R} - 1 > r $$

(25)

Since we know that $(Y_R - Y_{NR}) \geq 0$ and immediately after the deposit of KES 2,999 is paid $c > R$, the numerator must be higher than the repayment amount $R$ at any given point in time during the repayment cycle. Therefore, positive interest rates can be charged and there is no sign of enforcement problem in this market.

Our comparison between cash-based and SHS-based microcredit models shows the latter’s superiority in addressing moral hazard, adverse selection and the enforcement problem. At the very least this suggests that a market for SHS-based microcredit services, based on M-Kopa’s structure, does not suffer significantly from endogenous market failure. Our analysis could further have benefited from looking at the potential effects of clean energy usage relative to kerosene, for the household but also globally. Furthermore, subsequent studies should account for demand-side factors to gauge public perception and needs. We have
generally modelled the impact of SHS introduction on household utility, but with empirical research there is the potential to further uncover context-specific effects on households.

**Conclusion**

In conclusion, we have shown how despite ingenious methods that utilise social capital, cash-based microcredit has failed to show significant results in poverty alleviation. We questioned the income-based entrepreneurial approach for addressing poverty, and suggested one that focuses on enlarging the ‘functionings’ of individuals. This viewpoint leads us to take a closer look at the recent asset-based microcredit models that utilise technological innovation. M-Kopa’s SHS-backed microcredit approach exemplified a viable alternative to traditional cash-based models, able to mitigate moral hazard, adverse selection and the enforcement problem to a larger degree. A subsequent step calls for greater networking and industry best practice sharing between microcredit organisations and RET producers for communally beneficial ventures. We recommend further investigation into the sociological repercussions of asset-based microcredit alongside country-specific RCT’s to evaluate empirical results of poverty alleviation after the introduction of SHS. Due to the novel nature of asset-based microcredit these questions are yet to be answered within development literature.
Bibliography


Appendix:

Appendix 1: Plummeting Cost of Solar Modules

Appendix 2: Expected return to traditional microcredit lenders as a function of interest rate, $E(r)$. (Assumption 6 in section 2.1)
**Appendix 3: Randomized Controlled Experiments: proof of unbiased estimator of treatment effect**

\[ Y_i = \beta_0 + \beta_1 X_i + u_i \]

Where \( X \) is the randomly assigned treatment on each individual or community, \( i \). \( Y_i \) is the chosen factor to measure before and after treatment is given (e.g. household income, total consumption expenditure or number of self-employment activities managed by women), \( \beta_0 \) is the regression constant and \( u_i \) the error term that captures all other variation for the individual.

Since \( X \) is randomly assigned, \( E(u_i | X_i) = 0 \).

\[ \therefore \beta_1 = \beta_1 \text{ or the Ordinary Least Squares regression yields an unbiased estimator of the treatment effect } \beta_1 \text{ in an ideal RCT.} \]

**Appendix 4: A Closer look into the Diminishing Marginal Returns to Capital Theory**

Production is increasing with capital but at a diminishing rate. Due to the poor holding inefficient levels of capital, they would be situated on the left hand side of the graph and any increase in levels of capital will give a larger increase in production capability compared to if they were situated with further capital.
Appendix 5: A Closer look into the Marginal Returns and Overall Returns

Marginal return is the change in returns when investment in capital increases by one unit. Evidence shows a high marginal return in small businesses (with a low level of capital) but if initial investment was small in itself, a high percentage increase in returns would still fail to yield a transformative results. With the curve slowly tapering off as the stock of capital increases, marginal return will also start to fall. As a result, the small scale of businesses explains why overall returns are often low.

Banerjee and Duflo (2011: 216)
<table>
<thead>
<tr>
<th></th>
<th>Bosnia and Herzegovina (1)</th>
<th>Ethiopia (2)</th>
<th>India (3)</th>
<th>Mexico (4)</th>
<th>Mongolia (5)</th>
<th>Morocco (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liability</td>
<td>Individual Lending</td>
<td>Joint Liability Lending</td>
<td>Joint Liability Lending</td>
<td>Joint Liability Lending</td>
<td>Individual and Joint Liability Lending</td>
<td>Joint Liability Lending</td>
</tr>
<tr>
<td>Time between treatment and End-line survey</td>
<td>14 months</td>
<td>36 months</td>
<td>15-18 months</td>
<td>Average exposure 16 months</td>
<td>19 months</td>
<td>24 months</td>
</tr>
<tr>
<td>Loan term length</td>
<td>Average 15 months</td>
<td>12 months</td>
<td>12 months</td>
<td>4 months</td>
<td>3-12 months for group loans and 2-24 months for individual loans¹²</td>
<td>3-18 months</td>
</tr>
<tr>
<td>Interest rate charged (APR)</td>
<td>22%</td>
<td>12%</td>
<td>24%</td>
<td>110%</td>
<td>26.8%</td>
<td>14.5%</td>
</tr>
<tr>
<td>Market interest rate (APR)</td>
<td>27.3%</td>
<td>24.7%</td>
<td>15.9%</td>
<td>145%</td>
<td>42.5%</td>
<td>46.3%</td>
</tr>
</tbody>
</table>

**Effect of Microcredit Introduction (coefficients of variables with a treatment dummy, adapted to interpret as % change from control group)**

<table>
<thead>
<tr>
<th></th>
<th>Income effects</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-employment Activities</td>
<td>0.060 (0.029)**</td>
<td>-0.247 (0.219)</td>
<td>0.024 (0.062)</td>
<td>-0.016 (0.037)</td>
<td>0.131** (0.056)</td>
<td>-0.018 (0.012)</td>
</tr>
<tr>
<td>Wages</td>
<td>-0.080 (0.029)***</td>
<td>0.167 (0.286)</td>
<td>-0.176 (0.120)</td>
<td>0.006 (0.028)</td>
<td>-0.5963 (0.447)</td>
<td>-0.667 (0.030)**</td>
</tr>
<tr>
<td>Profits</td>
<td>0.2316 (0.187)</td>
<td>N.A</td>
<td>0.475 (0.421)</td>
<td>0</td>
<td>0.1784 (0.197)</td>
<td>0.221 (0.134)*</td>
</tr>
</tbody>
</table>

**Consumption effects**

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¹¹ Only the studies in India and Mongolia have an End-line 2. Since they are significantly further from the treatment date, we shall focus on end-line as a point of comparison between the studies.

¹² Due to lack of results on relevant poverty indicators from the Individual Lending Approach we shall only be analysing results from the Joint Liability Lending model.
<table>
<thead>
<tr>
<th>Temptation goods</th>
<th>-0.160* (0.088)</th>
<th>N.A</th>
<th>-0.105* (0.059)</th>
<th>-0.061** (0.031)</th>
<th>0.202 (0.344)</th>
<th>-0.092*** (0.028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable goods</td>
<td>0.009 (0.165)</td>
<td>N.A</td>
<td>0.170* (0.098)</td>
<td>N.A</td>
<td>0.002</td>
<td>0.281</td>
</tr>
</tbody>
</table>

**Social Effects**

<table>
<thead>
<tr>
<th>Share of children in school (different age groups)</th>
<th>6-15</th>
<th>16-19</th>
<th>5-15</th>
<th>16-20</th>
<th>5-15</th>
<th>16-20</th>
<th>4-17</th>
<th>5-15</th>
<th>16-20</th>
<th>5-15</th>
<th>16-20</th>
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<tbody>
<tr>
<td>Temptation goods in this regard consists of spending on festivals and celebrations.</td>
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<tr>
<td>Banerjee et al (2015) segregate effects into boys and girls. We are looking to compare with other papers but are unable to aggregate the results for girls and boys due to unavailability of data percentages of boys and girls going to school at the baseline. Therefore, we have chosen to use the results for boys since we assume a larger percentage of the total population of children going to school are boys evidenced by data from UNICEF (2013).</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Women Empowerment (different indicators)</th>
<th>N.A</th>
<th>Fraction of decisions with woman’s involvement</th>
<th>Index of women’s dependence/empowerment</th>
<th>Number of household issues she has a say on</th>
<th>N.A</th>
<th>Index of women independence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index consists of 16 outcomes that reflect changes in women’s bargaining power: decisions on food, clothing, healthy, home purchase and repair, education, durable goods, gold and silver, investment; levels of spending on school tuition, fees, and other education expenses; medical expenditure; teenage girls’ and teenage boys’ school enrolment; and counts of female children under one year and one-to-two years old. Taken verbatim from Banerjee et al. (2015: 49).</td>
<td></td>
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</tbody>
</table>

| Decision making power of women who are not single. The number of issues surveyed are 4, details of which household issues are not given in (Angelucci et al. 2015: 172) |

| Effect of the sum of 14 standardized measures (measures include: at least one woman in the household has currently an own activity, decides by herself on activity assets, buys activity assets herself, decides by herself on activity inputs, buys inputs herself, decides what to produce, commercializes production, decides by herself on commercialization, makes sales herself, had an own activity in the past five years, is allowed to go to the market by herself, is allowed to take public transportation by herself, is allowed to visit family by herself, is allowed to visit friends by herself) Each measure is coded so that 1 reflects independence and 9 reflects lack of independence. Index explanation is taken verbatim from (Crepon et al 2015) |

Standard Errors in parenthesis

***p<0.01, **p<0.05, *p<0.1