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Working Paper 136

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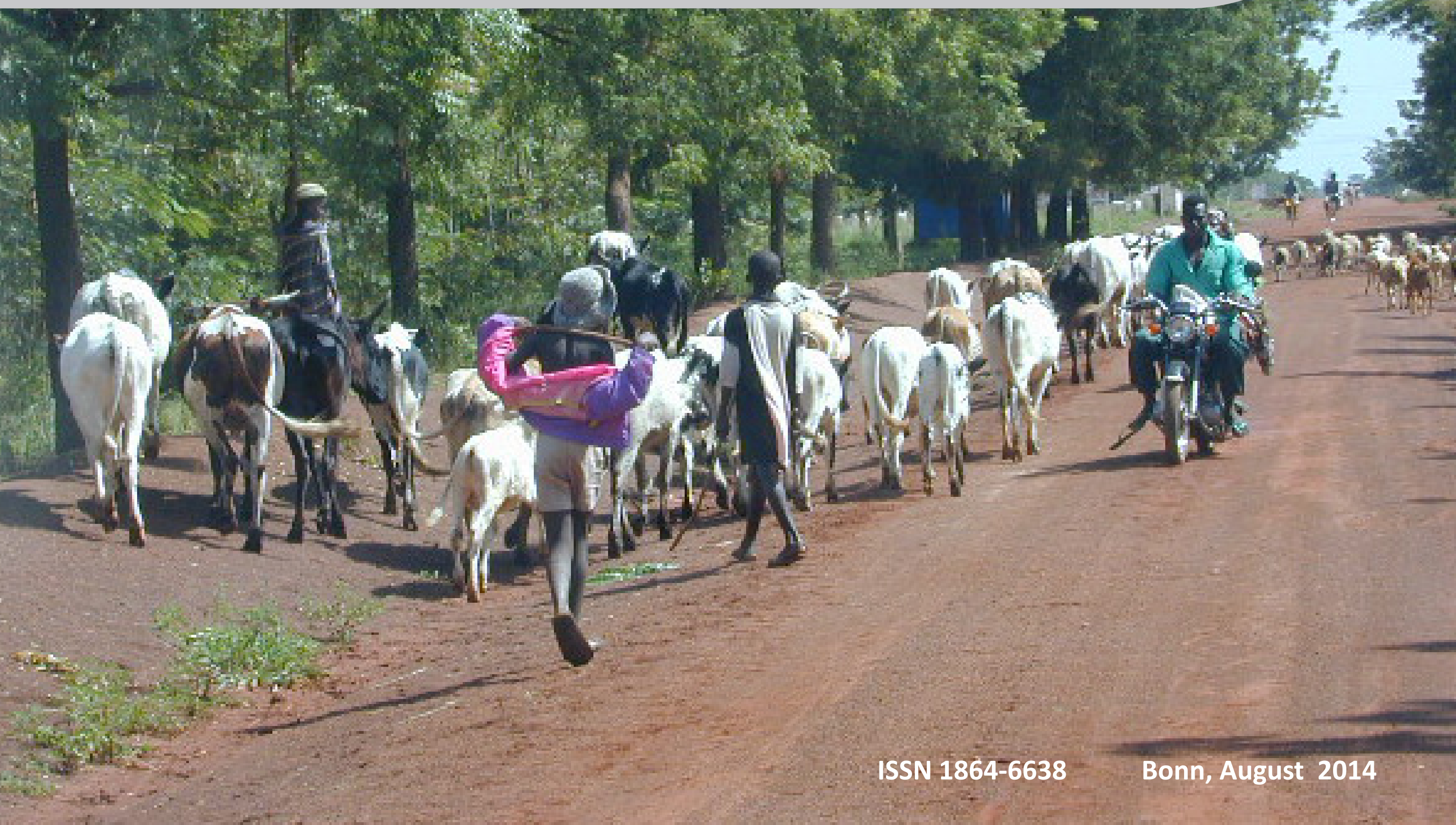
Theoretical support for matching technological and institutional innovations



ISSN 1864-6638 Bonn, August 2014

ZEF Working Paper Series, ISSN 1864-6638
Department of Economic and Technological Change
Center for Development Research, University of Bonn
Editors: Joachim von Braun

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Theoretical support for matching technological and institutional innovations

Deden Dinar Iskandar and Franz Gatzweiler

Abstract

The rural poor are often marginalized and restricted from access to markets, public services and information, mainly due to poor connections to transport and communication infrastructure. Despite these unfavorable conditions, agricultural technology investments are believed to unleash unused human and natural capital potentials and alleviate poverty by productivity growth in agriculture. Based on the concept of marginality we develop a theoretical model which shows that these expectations for productivity growth are conditional on human and natural capital stocks and transaction costs. Our model categorizes the rural farm households below the poverty line into four segments according to labor and land endowments. Policy recommendations for segment and location specific investments are provided. Theoretical findings indicate that adjusting rural infrastructure and institutions to reduce transaction costs is a more preferable investment strategy than adjusting agricultural technologies to marginalized production conditions.

Keywords: Optimization, Rural Poverty, Technology Adoption, Theoretical Analysis, Transaction Cost

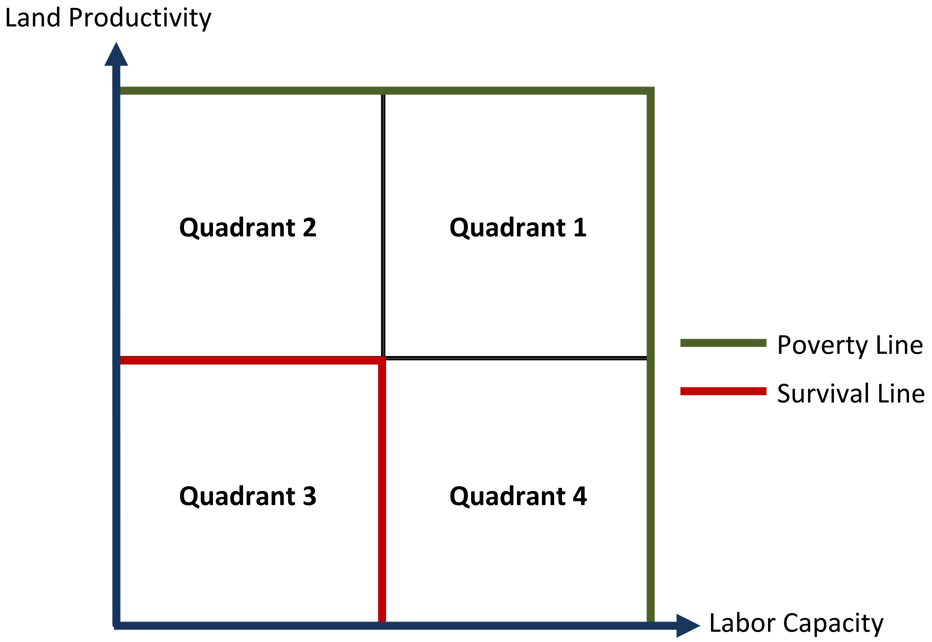
1 Background

This paper seeks to provide the theoretical support for intervention to increase the income generating capacity of the rural farm households below the poverty line. In particular, we observe the impact of technology adoption and the transaction cost effects on the income generation capacity in specific segments of the rural poor. There is a role for agricultural technology innovations to influence the poor directly by lifting constraints and increasing the output level of on-farm production (Irz et al., 2001). An empirical study from Mendola (2007) also emphasizes the potential role of technology to reduce poverty through the improvement of smallholder's production capacity.

In contrast to the economics of organization where transaction costs are defined as costs which occur "… when a good or service is transferred across a technologically separable interface."(Williamson 1985: 1), this paper defines transaction costs as the costs that create barriers between rural households and input and output markets, and restrict market access, communication and interaction. These costs mainly include transportation costs, due to the lack of well-maintained roads, long distances between the rural households and the market, and lack of affordable public transport facilities. Transaction costs also arise from the poor communication infrastructure for accessing and exchanging information regarding markets, products, and prices.

According to Reardon et al. (2001), insufficient access to public infrastructure raises entry barriers to more profitable labor markets. Renkow et al. (2003) examine the magnitude of fixed transaction costs that hamper the access to markets for subsistence farmers in Kenya. They predict that the impact of high transaction costs on the farmers' income is equal to the tax of 15%. Therefore, the impact of infrastructure investment on farmers' welfare is equivalent to cutting the tax of identical size. A study of Stifel and Minten (2008) on transaction costs and poverty in Madagascar finds that the incidence of rural poverty increases with increasing remoteness, and the yields of major crops and the utilization of agricultural production inputs fall significantly with distance to the market.

Figure 1: The segmentation of rural farm households based on land and labor endowment



Our study categorizes the rural farm households below the poverty line into four segments according to labor and land endowments within the marginality framework of von Braun and Gatzweiler (2014). The households in the first segment are characterized by relatively higher labor and land productivities. The households in the second segment featured by higher land, but lower labor productivities, on the other hand, the households in the fourth segment posses lower land productivity and higher labor capacity. The third segment represents the households under extreme poverty, with low land and labor capacities. In this study, these extremely poor households will be referred to as the households under survival line, since their main concern is to fulfill their basic needs for survival.

2 Theoretical analysis

2.1 The optimization problem of rural households under the poverty line

The income for the rural farm households is generated from the revenue of agricultural production (on-farm activities) and the revenue of renting out the factor inputs, mainly labor, to off-farm activities. The rural farm households below the poverty line are assumed to depend on two primary inputs for agricultural production: land and labor. In addition to these main inputs, farm production also requires farming production input such as farming equipment, fertilizer and seeds. We assume that the objective of the household is to maximize total household income from on- and off-farm activities. After the introduction of technology, the objective function of rural households is formulated in the following equation,

$$\underset{X,\hat{X},\tilde{X},V}{Max}\left(\frac{1}{T}\left((p.Y)+\sum_{i=1}^{n}\left(\hat{w}_i.\hat{X}_i\right)\right)-T.\left(\sum_{i=1}^{n}\left(\tilde{w}_i\cdot\tilde{X}_i\right)+\sum_{j=1}^{m}\left(c_j.V_j\right)\right)\right) \quad (1)$$

S.t. $$\sum_{i=1}^{n}\left(X_i+\hat{X}_i\right)\leq\sum_{i=1}^{n}\left(\overline{X}_i+\tilde{X}_i\right) \quad (2)$$

$$T.\left(\sum_{i=1}^{n}\left(\tilde{w}_i\cdot\tilde{X}_i\right)+\sum_{j=1}^{m}\left(c_j.V_j\right)\right)\leq B_i \quad (3)$$

Where $$Y=\prod_{i=1}^{n}\left(X_i^{\alpha_i}\right).\prod_{j=1}^{m}\left(V_j^{\beta_j}\right) \quad (4)$$

The income from on-farm activities is depicted by $(p..Y)$, where Y stands for the aggregate output of farm activities with p as the respective market price. Farm production is formulated as Cobb-Douglas production function. Production output is determined by the production inputs (X_i), where i represents different types of input. Each input has a different elasticity, α_i, that represents the percentage of change in agricultural production output resulting from a one percentage change in the input i. The technology adopted also contributes to the farm production. The technology used in the production process is indicated by V_j, where j refers to different types of technology. The productivity output elasticity of each technology, β_i, indicates the percentage change of farm output arising from a one percent change in the adoption of technology j. The production function is further characterized by $(\partial Y/\partial X^{\alpha}>0)$ and $(\partial Y/\partial V^{\beta}>0)$, meaning that the production will increase with production input and adopted technology. The revenue generated from off-farm activities is formulated as $\left(\hat{w}_i.\hat{X}_i\right)$, where $\left(\hat{w}_i\right)$ and $(\hat{X}_i)$ represent the price and the volume of input i used for other productive activities outside the farm household.

The total revenue of on-farm and off-farm activities should be adjusted by the transaction costs, T. The transaction costs occur because of spatial marginality and exclusion, specifically the difficulty to access the market because of the lack of public infrastructure and access to market information. The actual revenue will be discounted by transaction costs, since a certain proportion of household income needs to be spent to reach the market for selling farm output and buying households' production input.

The costs of generating the household income can be divided into production costs and the costs of technology adoption. The production costs, $\left(\tilde{w}_i \cdot \tilde{X}_i\right)$, indicate the costs of production inputs that are not available in the household. $\tilde{X}_i$ indicates the input i imported from outside the households with $\tilde{w}_i$ as its respective price. The cost of adopting technology is formulated as $\left(c_j \cdot V_j\right)$, where c_j is the price to adopt technology j. The presence of transaction costs (T) will increase the technology adoption costs, since the households have additional expenditures for reaching the input or technology market..

Equation (2) indicates the resource constraint faced by the households. The input i used for on-farm activities (X_i) and off-farm activities ($\hat{X}_i$) is limited by the availability of the total input i, which is composed of the households' input endowment ($\overline{X}_i$) and the input rented in from outside the households ($\tilde{X}_i$). Equation (3) is the budget constraint confronted by the household, which indicates that the total costs of employing additional inputs and adopting technology should not exceed the available production budget (B).

Given the input and budget constraints, the rural households maximize the total income by deciding on the optimal amount of choice variables. Those variables include the amount of production input used for on-farm activities (X_i), the amount of input used for off-farm activities ($\hat{X}_i$), the amount of additional input to be hired from outside the households ($\tilde{X}_i$), and the extent of adopted technology to be used for on-farm activities $\left(V_j\right)$.

The following Lagrangean equation formulates the maximum income function for the household under the specified input and budget constraints.

$$
\begin{aligned}
L = \frac{1}{T}\left(\left(p.Y\right) + \sum_{i=1}^{n}\left(\hat{w}_i.\hat{X}_i\right)\right) - T.\left(\sum_{i=1}^{n}\left(\tilde{w}_i \cdot \tilde{X}_i\right) + \sum_{j=1}^{m}\left(c_j.V_j\right)\right) \\
+ \lambda_1\left(\left(\overline{X}_i + \tilde{X}_i\right) - \left(X_i + \hat{X}_i\right)\right) + \lambda_2\left(B_i - T.\left(\sum_{i=1}^{n}\left(\tilde{w}_i \cdot \tilde{X}_i\right) + \sum_{j=1}^{m}\left(c_j.V_j\right)\right)\right)
\end{aligned}
\tag{5}
$$

The Lagrange multipliers in equation (5), λ_1 and λ_2, measure the infinitesimal change of the generated income resulting from infinitesimal changes in the constraints. In the constrained optimization, λ_1 and λ_2 could be interpreted as marginal loss of the generated income due to the reduction in the availability of inputs and budget respectively. These multipliers could also be interpreted differently as the marginal *income* of the *increase* in the available inputs and household budget.

Taking the first derivative of the Lagrangean equation will give the marginal income of each choice variable, i.e change in the generated income by one unit change in the choice variable.

$$
\frac{\partial L}{\partial X_i} = \frac{1}{T}.\left(\frac{p.\alpha_i.V_j^{\beta_j}}{X_i^{(1-\alpha_i)}}.\right) - \lambda_1 \tag{6}
$$

$$\frac{\partial L}{\partial \hat{X}_i} = \frac{1}{T}.\hat{w}_i - \lambda_1 \quad (7)$$

$$\frac{\partial L}{\partial V_j} = \frac{1}{T}.\left(\frac{p.X_i^{\alpha_i}.\beta_j}{V_j^{(1-\beta_j)}} \right). - T.c_j.(1+\lambda_2) \quad (8)$$

$$\frac{\partial L}{\partial \tilde{X}_i} = \lambda_1 - (1+\lambda_2).T.\tilde{w}_i \quad (9)$$

Setting the equation (6) – (9) equal to zero will give the First Order Condition (FOC), the condition for the optimal level of each choice variable to maximize the income. Rearranging equation (6) equal to zero in term of (X_i) will give the condition for the optimal level of input i as following,

$$X_i = \left(\frac{p.\alpha_i}{T.\lambda_1}.V_j^{\beta_j} \right)^{\frac{1}{(1-\alpha_i)}} \quad (10)$$

To generate the maximal income, the level of utilized input i should be equal to the marginal income of the input and the extent of adopted technology, adjusted by the transaction cost and the marginal income loss by reducing the input availability i at the identical size as the employed input. The marginal income is determined by $(p.\alpha_i)$, the product of output price and input i elasticity. This optimal condition implies that the utilization of input i in on-farm activities will increase with the output price and the input elasticity i, and decrease with the transaction costs and the marginal costs of losing the input availability to the same amount as the utilized input.

Equation (10) suggests that the optimal allocation of the inputs on on-farm activities is determined by their elasticities. The higher the input elasticity, the more intensive the respective input could be used in the production. Let Ld stands for land and Lb represents labor. The households in segment 2 with relatively higher land productivity, but lower labor capacity, $\alpha_{Ld} > \alpha_{Lb}$, will make use of land more intensively. On the other hand, the households in segment 4 with relatively lower land productivity, but higher labor capacities, $\alpha_{Ld} < \alpha_{Lb}$, will rely more on the utilization of labor to generate income from agricultural production. In the segment 1 where households have equally higher level of land and labor capacities, and in segment 3 in which the households suffer from equally low level of land and labor capacities, the contribution of labor and land utilization on the generated income is evenly balanced, $\alpha_{Ld} = \alpha_{Lb}$.

$$\frac{X_{Ld}}{(p.\alpha_{Ld})^{\frac{1}{(1-\alpha_{Ld})}}} = \frac{X_{Lb}}{(p.\alpha_{Lb})^{\frac{1}{(1-\alpha_{Lb})}}} \quad (11)$$

The optimal condition for the allocation of those two inputs (Ld and Lb) on agricultural production is depicted in equation (11). When the households use two inputs, they will exhaustively use one particular input that gives the highest return (i.e input with higher elasticity) up to the point that the ratio of utilized input and the resulted marginal income between the two inputs is equal.

We can infer from the equation (10) and (11) that the presence of transaction costs, T, will reduce the optimal production input. Transaction costs discount the revenue from agricultural production. When the transaction costs increase, the optimal input to use in farm production will also decrease since the actual revenue generated from the utilization of input is declining.

The condition for optimal level of exported input for off-farm activities is given by the following equation,

$$\frac{1}{T}.\hat{w}_i = \lambda_1 \quad (12)$$

The level of input used for off-farm activities will be optimal if the marginal revenue, which is the price of the input i adjusted by transaction cost, is equal to the marginal loss of generated income due to the reduction of input i availability. If the marginal revenue earned from off-farm activities is higher than the marginal loss, the optimal choice for the farm households is to keep renting out the inputs. On the other hand, if the marginal loss is higher than the expected marginal revenue from renting out the inputs, then the rational household will keep the inputs for on-farm activities. In the presence of transaction cost, the revenue from off-farm activities will be discounted, since the household will have additional costs to reach the input market.

Combining the equation (11) and (12) will link the decisions about allocating the input between on–farm and off-farm activities.

$$X_i = \left(\frac{p.\alpha_i.V_j^{\beta_j}}{\hat{w}} \right)^{\frac{1}{(1-\alpha_i)}} \quad (13)$$

Equation (13) indicates that increasing wages for off-farm work will decrease the allocation of input i to on-farm activities. Assuming that the transaction costs affects both the optimal input to use in on-farm and off-farm activities at the same scale, the transaction cost will not influence the decision.

The optimal level of technology adoption is then depicted by the following equation,

$$V_j = \left(\frac{p.\beta_j}{T^2.c_j.(1+\lambda_2)} .X_i^{\alpha_i} \right)^{\frac{1}{(1-\beta_j)}} \quad (14)$$

Equation (14) says that the level of adopted technology j, (V_j), will be optimal if it is equalized to the marginal income of the adopted technology adjusted by the transaction cost and marginal income loss due to reducing budget at hand. The marginal income is formulated as the product of output price and the elasticity of adopted technology on the generated income $(p.\beta_j)$. The optimal level of adopted technology will increase with the output price and the elasticity of technology j, and decrease with the cost of obtaining the technology.

The contribution of technology to income generation does not work in isolation, but it is a joint action in which the utilization of production inputs also takes part. Therefore, the condition for optimal adoption of technology is also influenced by the elasticity of input i , $\propto_i$. The optimal level of technology adoption and its contribution to the income generation will increase (decrease) with a higher (lower) elasticity of the input production.

Equation (14) also indicates that the presence of transaction costs will reduce the optimal level of technology adoption at a multifold scale. Transaction costs hinder the adoption of technology in two ways, by discounting the actual revenue of production output and increasing the actual cost of acquiring the technology. Therefore, when the transaction costs and the price of technology are higher, it will be a rational option for the rural households to decrease the adopted level of technology.

$$T.\tilde{w}_i = \frac{\lambda_1}{(1+\lambda_2)} \tag{15}$$

Equation (15) demonstrates the optimal condition for employing additional input production from outside households. In this equation, λ_1 represent the marginal income from increasing the available input. The optimal level of additional input i will depend on the costs of acquiring the input i, the marginal income of increasing the availability of input i, and the marginal costs of losing the available budget. The households will start buying additional input i when the marginal income from increasing the input adjusted by the marginal cost of decreasing the current availability of budget[1] (as a consequence of the payment made to buy the input) are higher than the price of input i ($\tilde{w}_i$) adjusted by the transaction cost.

2.2 The optimization problem of rural households under the survival line

The extreme poor and marginalized rural households are under worse conditions. In our model, their capacities are constrained to fulfilling basic survival needs. The budget constraint they are living under, restricts them from adopting agricultural technologies or buying additional inputs to increase production. Therefore, the constraints in equation (2) and (3) are changed into the following equations,

$$X_i + \hat{X}_i \leq \overline{X}_i \tag{16}$$

$$Bp \leq \dot{T}\left(\left(\tilde{w}_i \cdot \tilde{X}_i\right) + \left(c_i \cdot V_i\right)\right) \tag{17}$$

$\dot{T}$ Is the transaction cost confronted by the extreme poor households. We can expect transaction costs to be higher for those households which are more marginalized, therefore $\dot{T} > T$. Under the new constraints, the objective function for extreme poor smallholders is the following,

$$\underset{X,\hat{X}}{Max} \sum_{i=1}^{n} \left(\frac{1}{\dot{T}} \left((p.Y) + \left(\hat{w}_i . \hat{X}_i \right) \right) \right) \tag{18}$$

[1] Spending the input for off-farm activities will reduce the available input at hand. This particular concept of cost covers the possibility that this reduction will create cost for income generation of the farmer.

From the equation above, it is obvious that the available option for the extreme poor households is limited to choosing the level of inputs to use in on-farm activities and to rent out their labor for off-farm activities. The problem of optimal input allocation for generating maximal income is different from the problem of the rural households in other segments, and formulated by the following Lagrangean equation,

$$L = \frac{1}{\dot{T}}\left(\left(p.Y_i\right) + \left(\hat{w}_i.\hat{X}_i\right)\right) + \lambda_1\left(\left(\overline{X} - \hat{X}\right) - X\right) \qquad (19)$$

First derivation of equation (19) results in the marginal income of each choice variable,

$$\frac{\partial L}{\partial X_i} = \frac{1}{\dot{T}}.\left(\frac{p.\alpha_i}{X_i^{(1-\alpha_i)}}.\right) - \lambda_1 \qquad (20)$$

$$\frac{\partial L}{\partial \hat{X}_i} = \frac{1}{\dot{T}}.\hat{w}_i - \lambda_1 \qquad (21)$$

While the marginal income of renting out labor input for off-farm activities is theoretically identical (equation (7) and (21) are exactly the same), it can be deduced from the equation (20) that as the extreme poor have less available inputs, the marginal income from input utilization for the extreme poor households is lower than that of the other households. That is reasonable since the extreme poor households have not adopted (modern) technology in their agricultural production, whereas the production output is a joint result of all input utilization in interaction.

The conditions for the optimal level of input allocated for on-farm and off-farm activities are given in the following equations,

$$X_i = \left(\frac{p.\alpha_i}{\dot{T}.\lambda_1}\right)^{\frac{1}{(1-\alpha_i)}} \qquad (22)$$

$$\frac{1}{\dot{T}}.\hat{w}_i = \lambda_1 \qquad (23)$$

Equation (22) suggests that the optimal input used in the on-farm activities will increase with output price and input elasticity, and decrease with transaction cost and the marginal cost of increasing input availability. This optimization behavior is equal to that of the less poor households, however, due to the absence of technology adoption, the optimal level of input utilization will be lower than the optimal level of the less poor households.

The decision of renting out the input for off-farm activities is identical to the other households (equation (12) and (23) are identical). It depends on wages, transaction costs, and marginal income loss by reducing the current availability of input to spend outside the households. If the wage, after being adjusted by transaction costs, is higher than the marginal income loss for accessing labor markets, then the households will keep renting out the input up to the point where the wage and the marginal loss are equal.

Combining the equation (22) and (23) will link the decisions about allocating the input between on–farm and off-farm activities.

$$X_i = \left(\frac{p.\alpha_i}{\hat{w}} \right)^{\frac{1}{(1-\alpha_i)}} \qquad (24)$$

Equation (24) indicates that the increase in the revenue by renting out input i to off-farm activities $(\hat{w})$ will decrease the utilization of input i for agricultural production on-farm. The amount of inputs i that the extreme poor households intend to keep on-farm activities is lower than that of the less poor households. Since the marginal income of the input i is lower, the extreme poor households are willing to rent out more input (labor) for generating household income.

3 Theoretical support for governmental intervention

From the theoretical analysis, we can infer that the income generation capacity of rural households below poverty line is determined by the input elasticities, the technology adoption level, and the transaction costs. Particularly for the extreme poor households, special attention should be given to increase their available household budget for enabling them to adopt productivity increasing technologies to an extent that they rather prefer to invest their labor on-farm than renting it out. Increasing the income of poor rural households requires the improvement of input elasticities and technology adoption, the reduction of transaction costs, and the budget injection for extremely poor households. For many extreme poor households an improvement of income elasticities and technology adoption could be a result of improving rural infrastructures, market access and land rights which would also reduce transaction costs and improve proximity. However, if improving proximity by adjusting rural infrastructure and reducing marginality is perceived as too costly, a likely alternative for many rural poor will be to migrate to less marginal areas with better proximity and better access to markets.

3.1 Budget injection for the extremely poor rural households

The extreme poor households are suffering from the lack of budgetary capacity to support their production beyond survival levels. Therefore, one option for increasing their income generating capacity are cash transfers from the government. Cash transfers have a direct increasing impact on the households' budget availability, moving the budget constraint from equation (3) to equation (17).

However, for the transfer to have a more permanent impact on sustainable income generation, cash transfers need to be large enough to cover the household's basic consumption needs, so that the rest of the cash transfer may be used for agricultural production, buying farming tools and seeds and acquiring technology. An example can be found in the 2005 cash transfer program in Zambia, which shows that 29% of received cash transfer in Kalomo district was invested in either livestock or agriculture inputs after the consumption of basic needs was satisfied (MCDSS and GTZ, 2005).

3.2 Improvement of technology adoption

We can see from the equation (14) that the level of technology adoption is deterred by the availability and the cost of obtaining the respective technology. The availability of technology and the cost of adoption could be defined as the function of government expenditure on research and development.

$$V_j = f(\dot{G}_j) \qquad (25)$$

$$c_j = f(\dot{G}_j) \qquad (26)$$

$\dot{G}_j$ is the government expenditure on research and development of agricultural technology j . V_j represents the technology j available for adoption by rural farm households with c_j as its respective price. The availability of technology j is characterized by $\partial V_j / \partial \dot{G}_j > 0$, indicating that the availability of technology increases as the government increases spending on research and development. On the other hand, the cost of the adoption of technology j is featured with $\partial c_j / \partial \dot{G}_j < 0$, meaning that the cost is decreasing with government expenditure on research and development. If the government provides the subsidy for producing technology, the availability of technology will increase at a lower price and the level of adoption will increase.

However, the financial capacity of households to acquire the available technology will be different between the poor households living adjacent to the poverty line and those who are extremely poor and living adjacent or under the survival line. Therefore, besides cash transfers, cheaper technology need to be made available to facilitate its adoption by the extremely poor households.

3.3 Improvement of inputs elasticities

Productivity improvements can also be achieved by improving inputs elasticity. Elasticity of input i is assumed to be the function of government investment I_i, which in turn is determined by the government spending on that particular program, $\ddot{G}_i$.

$$\alpha_i = f(I_i) \tag{27}$$

$$I_i = g(\ddot{G}_i) \tag{28}$$

Equation (27) and (28) is characterized by $(\partial\alpha_i / \partial I_i).(\partial I_i / \partial\ddot{G}_i) > 0$, indicating that the elasticity of input i will increase with government spending . For instance, to increase the elasticity of land, the corresponding government program could be the provision of a better fertilizer funded by the government. Aside from directly providing the fertilizer, the government could also support the program to help the households make their own fertilizer. For example, the practical training program conducted by the United Nations Development Programme (UNDP) in Northern Nigeria provides practical guidance on how to make compost heaps and green manure for fertilizer (Onvemaobi, 2012). The program now successfully yields better harvests for the rural households**.**

On the other hand, the increase of labor elasticity could be facilitated through the provision of training supported by the government. The role of households' labor in agricultural production is not only limited to providing the work-force to cultivate the crops, but also acting as decision makers and applying good agricultural practice. To succeed in farming, rural households need more training beyond basic literacy. They need training regarding the right crops to plant, the type and the quantity of required inputs, and the methods to utilize the limited resources with greater efficiency. A better skill and knowledge will lead to higher return on labor employment in agricultural production.

Another example is a training program conducted by the UNDP in Northern Nigeria providing a practical demonstration on better farming techniques (Onvemaobi, 2012). Other examples to increase the farming skill of the rural households are the farmer field schools. The season-long program enables the farmers to meet regularly and to learn new agricultural techniques. According to Davis et al. (2010), the farmer field schools have resulted in important improvements in farmer productivity. In particular, this approach is beneficial for poor farmer with a low level of primary education.

To produce effective results, the program should be targeted to address the right problems. For example, the households with lower land productivity call for provision of better and safer fertilizer. On the other hand, the households with relatively lower labor capacity require practical training to increase their skills and knowledge. These ways, the optimal condition as indicated by equation (11) could be reached. Improving the education and skill of the farmer does not only enhance the labor elasticity, but also increase the technology absorption capacity. More educated and skilled smallholders will have a better capacity to adopt specific technologies and make use of it for accelerating income generation.

3.4 Reduction of transaction costs

Transaction costs result from the lack of public physical and institutional infrastructure and put a constraint to access the market. The difficulty in accessing the market impedes the opportunities to generate income. It reduces the market opportunity for agricultural products, decreases the returns to labor and land of on-farm activities, and increases the input costs as well as the costs of adopting technology. High transaction costs also reduce the opportunity of rural households to participate in labor markets for off-farm activities. Some situations of collective action and forms of technology can reduce those transaction costs, although investing in collective action itself can be a costly investment. The collective action problem usually arises because costs of exclusion are too high, however, when the costs of overuse, pollution or exploitation are even higher, collective action can become a worthwhile, despite costly, activity (Ostrom 2005, Olson 1965, Williamson 1975). Although they can also be reduced by collective action, transaction costs, T, are here formulated as the function of government expenditure on public infrastructure, $\overline{G}$,

$$T = f(\overline{G}) \tag{29}$$

The equation above is characterized by $\partial T / \partial \overline{G} < 0$, meaning that transaction costs will decrease with increasing government spending on public infrastructure. In the case of the poor households under survival line, equation (29) is slightly modified into $\dot{T} = f(\overline{G})$, where $\dot{T} > T$.

Increasing the provision of public infrastructure will increase the actual revenue of agricultural production and off-farm activities as well as lessen the cost of production, thus enhance the opportunities to generate income from agriculture. Public investments in transportation and communication infrastructure are particularly important as the attempts to reduce transaction costs.

Access to public infrastructure leads to a reduction of those transaction costs, which the poor rural households have to carry when they access the output and input markets. Lower transaction costs could change the structure of relative prices for the poor farmer. This change will enable the poor households to earn higher revenue from agricultural production and lower production cost, thus increase their income. Lower transaction costs also allow the poor farm households to acquire the necessary additional inputs and technology; hence encourage the improvement in agricultural production that leads to higher agricultural output.

Finally, lower transaction costs may induce a change in the allocation of labor input between on-farm and off-farm activities. When rural households commit to more than one income generating activity, the access to public infrastructure will influence the households' labor allocation decisions. The reduction of transaction cost due to the availability of public infrastructure will increase the opportunities for the poor rural households to participate in off-farm activities. On the other hand, lower transaction costs and improved public infrastructure, proximity and access to markets may change labor allocation decisions to on-farm activities.

4 Conclusion

The theoretical optimization model for decision-making of marginalized smallholders we have elaborated on assumes rational decision makers. The likelihood of poor and extremely poor smallholders making decisions as elaborated in this optimization framework is related to the extent that these smallholders act rationally. This study provides theoretical evidence for increasing the income generation capacity of the rural farm households below the poverty line by means of government interventions and collective action linked to the agricultural production process, like conditional cash transfers and improvements in institutional infrastructure and freedoms which encourage collective action. Particular concern should be given to the reduction of transaction costs, since high transaction costs reduce the revenue from on-farm as well as off-farm activities and increase the cost of using additional production inputs and adopting innovative technologies. Marginality is a relative concept and so is that of transaction costs. Although collective action is a costly undertaking, it is worthwhile investing in collective action to overcome market access barriers when the projected revenues compensate those costs for coordinating and organizing actions collectively.

Technology adoption, which has been advocated as a promising way to enhance agricultural production capacity of the poor, is not as effective for productivity growth under the presence of high transaction costs, as improving infrastructure and encouraging collective action. That is particularly relevant to marginalized smallholders and can be explained by the fact that technologies need to be embedded into an enabling environment which consists of knowledgeable experts and a technology based service infrastructure for supply and maintenance. The provision of public infrastructure and better institutions would lead to a reduction in transaction costs, encourage collective action and increase the income opportunities for the poor rural households, especially in the extreme poor segments of rural society.

Segmentation of poor households provides differentiated recommendation for intervention strategies. For instance, the extremely poor households living under the survival line need more provision of infrastructures to overcome access barriers and cheaper technology than the poor households adjacent to the poverty line. Investments to increase the input productivity also varies between different segments. Assuming that the households are rational, they will use those productive inputs which promise the highest return on income and thereby intensify production. Therefore, the government should invest in people first and enable them to invest in the input productivity increasing activity of their choice.

Investments in technology in segments of rural society in which there is insufficient absorption capacity reduces the returns on technology investment, even if the technology is adjusted to the specific agro-ecological conditions. Productivity growth is underperforming in those segments because the depreciation of human and social capital is larger than investments in social and human capital. Improving the institutional infrastructure and reducing transaction costs by improving education and information and secure property rights, would decrease societal depreciation, improve absorption capacities and make investments in technology innovations economically worthwhile.

From a broader agricultural development perspective, there is a trade-off between adjusting agricultural technologies to the marginalized production conditions of poor and extremely poor segments of rural society versus adjusting rural infrastructure and institutions for allowing an economically effective use of agricultural technologies. Theoretical findings indicate that adjusting rural infrastructure and institutions to reduce transaction cost is preferable. However, it has become obvious that institutional and technological innovations need to go hand-in-hand. Therefore, both strategies need to be further informed by a spatially specific approach.

Given the overall goal of productivity growth in agriculture, areas in which agricultural infrastructure is fragmented and marginalized will require investments in adjusting the technology to the locality. If these investments are not made, rural populations will most likely move to urban areas and human as well as agro-ecological potentials are lost. In areas in which agricultural infrastructure is less fragmented and marginalized the use of agricultural technology which allows the grasping of scale effects is economically advisable.

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University of Bonn

Working Paper Series

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Photo: ZEF

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Walter-Flex-Straße 3
D – 53113 Bonn
Germany

Phone: +49-228-73-1861
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