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Abstract

In this paper, we define three ordinal credit constraints levels and identify their effects on farmers' welfare through the agricultural productivity channel. We study the case of Burkina Faso, a country where women farmers exhibit unequal property rights with respect to men. Average treatment effects are estimated from an ordered switching regression model that corrects from the potential endogeneity that results of the selection into a given credit constraint level. The empirical analysis builds mainly on household survey data from Burkina Faso (MICS 2014). We verify that credit relaxation improves farmers welfare and productivity. We define two levels of credit constraint among those who do not obtain credit: high and medium constraint. Our estimates of treatment effects show that extending credit to those who are highly constrained implies a greater improvement in welfare and productivity than those who are considered to be medium constrained. This verifies that our three levels of credit constraint is more informative than a traditional dichotomous approach focused on having or not having access to credit. Most importantly, we provide new evidence that less empowered women farmers reduce their agricultural productivity as access to credit relaxes. This may result from the gender inequality in Burkina Faso's land property rights, which can fuel women's disempowerment and credit diversion.

Keywords: Household production, credit constraints, agriculture, welfare, gender
JEL Classification: D13; Q14; E21.

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1 Introduction

Agriculture is one of the key sectors driving economic growth in Sub-Saharan Africa and, as many authors have pointed out, agricultural growth-enhancing policies are likely to be the most effective at reducing poverty compared to those of other sectors (de Janvry and Sadoulet, 2010; Christiaensen et al., 2011). In agriculture, productivity improvements are determined by the ability to access a variety of resources, yet the literature identifies a systematic gender-based productivity gap that favors men and raises questions regarding the gender gaps in access to resources (Goldstein and Udry, 2008a; Akresh, 2005; wa Gĩthĩnji et al., 2011; Slavchevska, 2015). In this regard Morsy (2020), among others, finds that women across countries and sectors suffer the most from financial constraints.The main reason for this gap is related to the differences in asset ownership which is sustained by social norms. This gender asset gap in turn has a negative impact in agricultural productivity (Food and Organization, 2011). Consequently, countries such as Burkina Faso, where women suffer from significant inequalities in land property rights (Theriault et al., 2017), are expected to exhibit gender gaps in access to credit, welfare and agricultural productivity (Ali et al., 2014). Such gaps may be exacerbated by women empowerment inequalities that may disrupt the transmission channel between financial access and agricultural productivity (Garikipati, 2008; Goetz and Gupta, 1996)

Furthermore, when credit access is considered a binary status (full access or no access), as is the common practice in the literature, it ignores a potential non-negligeable heterogeneity within those labeled as having or not having access to credit. The dichotomy perspective of credit access appears to fail to capture the different potential forms of credit constraints deriving from both supply and demand factors of credit market (Jappelli, 1990; Boucher et al., 2009). These factors rise asymmetry information issues that Boucher et al. (2009) highlight in three mechanisms preventing farmers from accessing credit: First, a quantity-rationing mechanism might occur when farmers apply for a credit to a lender (Bank, Microfinance institution, etc.) but do not get it. Conversely, farmers may voluntarily withdraw themselves. Jappelli (1990) refers to them as discouraged borrowers and points out the importance to consider this group to avoid biased estimates. Second, a risk-rationing mechanism may rise when farmers self-select out from credit market because of the unwillingness to bear the minimum risk of the collateral requirement. Third, a transaction-cost mechanism may be at play when farmers voluntarily exclude themselves because they cannot afford the basic requirements, such as application fees or paperwork, to be eligible for potential credit.

In this paper, we seek to identify how different levels of credit constraints affect male and female farmers' household welfare. Because credit constraint effects could be channeled through agricultural productivity, we also identify the credit constraints' effects on households' plot yields. We distinguish between three credit constraint levels that reflect the quantity, risk and transaction-cost mechanisms, where these levels are identified from the direct elicit elicitation method adapted from Boucher et al. (2009) approach. First, we define highly credit constrained farmers as the ones in need of credit who self-select out of the credit market because of their low endowments which prevent them to meet the basic requirement to be eligible for potential credit. Second, medium credit constrained farmers participate in the credit market but do not get credit because they fail to reach the minimum level of collateral set by lenders. Finally, low credit constrained farmers participate in the credit market and get credit.

Our empirical analysis builds on Burkina Faso's nationally representative sample survey from the 2014 Multisectoral Continuous Survey (MICS 2014). We focus on welfare and productivity improvements by estimating the average treatment effects on the treated (ATET) and untreated (ATU) subpopulations, from a regression-based approach. In this setup, it can easily be argued that credit constraints are not exogenous to either welfare or households' farm productivity. We address this concern by estimating a multinomial tobit model – a generalization of an endogenous switching regression – where our three credit constraint intensity levels define three endogenous welfare and productivity regimes. The causal effect of the endogenous credit constraint level is identified through model nonlinearities. Nevertheless, in order to improve empirical identification, we explore the literature on social capital, according to which households' social networks determine access to credit (Ali et al., 2014). This makes it possible to identify suitable exclusion restrictions whose exogeneity and weakness are formally tested by means of an auxiliary linear model under an instrumental variable estimation framework. More specifically, we rely on membership in an association or a decision-making body of an association and the level of network inclusion at the department level as exclusion restrictions (Grootaert et al., 1999). We perform an additional investigation on women's productivity effects (ATET and ATU) by segmenting our analysis into high and low women empowerment sub-samples according to a regional indicator brought to our microdata from a DHS survey.

According to our ATET estimates, we verify that credit constraints relaxation improved consumption per capita, for male farmers from HCC (highly credit constrained) to LCC (low credit constrained) by about 9 per cent, while the improvement from MCC (medium credit constrained) to LCC increased welfare by 6 per cent. The ATU estimates for the men sample show similar magnitudes than their ATET.

In the case of women, the ATET are larger: credit constraints relaxation from MCC to LCC and from HCC to LCC imply an increase of consumption per capita of about 31 and 54 per cent respectively. These seemingly implausible magnitudes contrast with their ATU which show a 11 and 13 per cent improvement when transitioning from MCC to LCC and from HCC to LCC respectively. To further explore the main transmission channel behind these results, we estimated the credit constraints effects (ATET and ATU) on farmer's productivity with a particular focus on women. Like in our consumption per capita estimates, we find that men and women farmers improve their productivity the most when transitioning from HCC to LCC than when transitioning from MCC to LCC. This heterogeneous effects confirms the relevance of our three credit constraints approach -LCC, MCC and HCC - with respect a binary approach polarized between having access to credit (LCC) or not (MCC or HCC). We provide a closer look at the effects of women's credit constraints on productivity by segmenting our estimates into high and low empowerment subsamples. As expected, we find positive effects on productivity as a consequence of credit relaxation in high female empowerment regions. Conversely, we find negative effects in the low empowerment regions, thus providing evidence of women's vulnerability and potential credit diversion. This finding is in line with Garikipati (2008), who identifies that weak ownership rights, credit diversion and women disempowerment are intrinsically related.

This paper contributes to the literature by identifying the credit constraint relaxation effects on a sui generis country context where women suffer from significant inequalities in land property rights (Theriault et al., 2017). Our results contribute to the sparse body of evidence on the moderating role of women's empowerment in the relationship between credit relaxation and agricultural productivity. An additional contribution is the definition of a three-tiered credit constraint framework. This definition allows for more policy-relevant implications of potential credit access easing interventions. Differentiating the credit constraints in line with the three mechanisms of information asymmetry, allows for fine-tuning the potential policy measures of relaxing credit constraints (Boucher et al., 2009). A policy intervention aiming to relax terms and conditions (credit supply) or reinforce farmers endowments (demand for credit), might enable them to shift from highly credit constrained to medium credit constrained by addressing the transaction-cost mechanism. Our findings would allow to document the ex-ante impact of such policies on the households welfare and productivity.

The rest of the paper proceeds as follows. Section 2 provides an outlook to Burkina Faso's agricultural context. Section 3 provides a conceptual framework that links financial access, agricultural productivity and welfare under a gender perspective. Section 4 presents the econometric specification and descriptive statistics while section 5 provides results. Section 6 concludes.

2 Background

Agriculture accounts for about a third of Burkina Faso's GDP, and the country's employed labor force is mostly concentrated in agriculture (90% of the workforce in 2012).[1] The most important government policy program for the agricultural sector, the National Program for the Rural Sector (PNSR), was first implemented for the 2011-2015 period. The program is currently in its second phase (PNSR II, 2016-2020) and focuses mainly on food security, improving rural populations' revenues and the sustainability of natural resource use. In terms of access to funding, the World Bank lent 100 million USD in 2019 under the *Financial Inclusion Support Project* (FISP) to support Burkina Faso's financial inclusion efforts as targeted by its *Politique Nationale pour le Développement Economique et Social* (PNDES). The FISP focuses mainly on the constraints faced by women and women-led enterprises.

Despite growing evidence regarding the relationship between the role of women in agriculture and productivity in many countries, little is known about Burkina Faso, where the majority of people, particularly those in rural areas, are in the

[1] Country Fact Sheet on Food and Agriculture Policy, 2014, Food and Agriculture Policy Decision Analysis (FAPDA), FAO.

agriculture sector and poor. Most importantly, the country is characterized by differences in property rights in rural areas in general, and especially between men and women, where women have limited property rights. This discourages them from making investments in their plot such as introducing soil and water conservation techniques (Kazianga and Masters, 2002; Theriault et al., 2017).Similarly, Haider et al. (2018) find that the likelihood of fertilizer adoption is significantly lower among female plot managers in Burkina Faso than their male counterparts.

The work of Udry et al. (1995) focusing on Burkina Faso's agricultural sector shows that there were significant inefficiencies in production factor allocation across plots managed simultaneously by household members. They found that there was a room for productivity gains of about 10%-15%. A more recent study Combary and Savadogo (2014), explain some of the inefficiencies in Burkina Faso's cotton sector, relating them to a drop in total factor productivity, which is also likely to explain inefficiencies in other crops. Kazianga and Wahhaj (2013) apply an intra-household resource allocation model to a social institution that is specific to certain ethnic groups in Burkina Faso. In this institution, the household head (usually a man) has a particular obligation to provide for the entire household using the proceeds from the common plot. The authors found that farm plots managed by male household members use family labor more intensively and achieve higher yields on average than those managed by female household members from the same household. However, no such gender difference exists among private plots. Croppenstedt et al. (2013) suggest that women are not worse farmers than men in a technical sense. Instead, they argue that women often face constraints in their access to and demand for production inputs, which in turn impact their farms' yields.

3 Conceptual framework

Unlike the literature that focuses on measuring credit constraints effects as a dichotomous state, our approach seeks to identify welfare and productivity outcomes at different credit constraint levels. This is more informative for policy-making purposes, as it acknowledges the existence of certain degrees of lack of access to credit deriving from different asymmetry information mechanisms introduced by Boucher et al. (2009). Without refereeing to asymmetry information issues, Kuntchev et al. (2012) suggest also a framework with a broad concept of credit constraints that includes four levels ranging from Fully Credit Constrained

(FCC) to Not Credit Constrained (NCC). By construction, these levels of credit constraints are implicitly underlying to the asymmetry framework by Boucher et al. (2009). This approach was developed to analyze the World Bank's SME surveys and considers firms that do not need credit as "not credit constrained." We argue that these firms' credit (supply) constraints may remain censored because of their abundant capital. Thus, such a taxonomy may not be very informative in a policy-making context that seeks to better target the population in greater need of credit.

Furthermore, most of the available studies on the role of gender in agriculture point to gender inequalities in endowments as a main driver of agricultural productivity gaps. There is evidence that women lack access to land and agricultural inputs, but they also have limited or no access to credit. They are therefore less likely to invest in land and more advanced technologies, on top of facing some other institutional or traditional constraints (Morsy, 2020; Horrell and Krishnan, 2007; Quisumbing, 1996; Tiruneh et al., 2001; Udry et al., 1995).

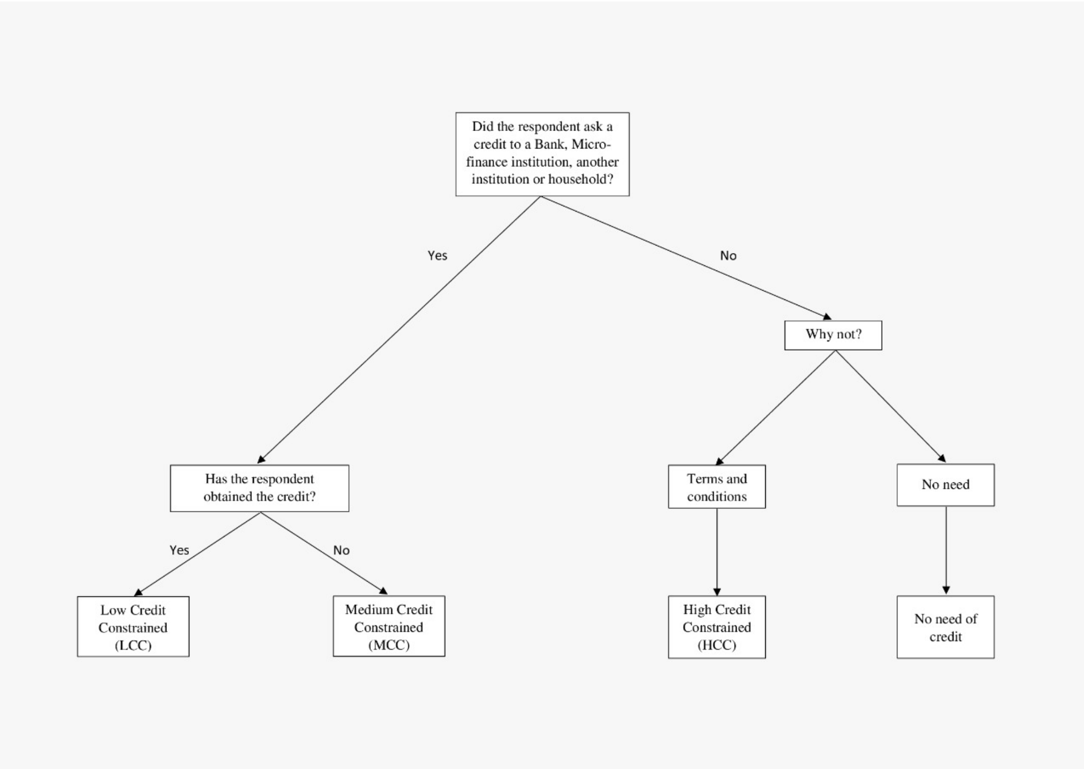
Hence, we distinguish three constraint levels depending on farmers' endowments and the minimum endowment required to gain access to some credit (c_j). While the credit constraint level is denoted by $R \in \{0, 1, 2\}$, farmer endowments are denoted by S^*. As mentioned earlier, our research question focuses on the population of farmers who are vulnerable to credit constraints, i.e., farmers who are in need of credit:

$$\text{Credit Constraint (R)} = \begin{cases} 0 \text{ - Low Credit Constraint (LCC)} & \text{if } S^* > c_2 \\ 1 \text{ - Medium Credit Constraint (MCC)} & \text{if } c_1 < S^* \leq c_2 \\ 2 \text{ - High Credit Constraint (HCC)} & \text{if } S^* \leq c_1 \end{cases} \tag{3.0}$$

We denote the most credit constrained farmers as Highly Credit Constrained (**HCC**). They need credit but self-select out of the credit market because they believe their endowments S^* do not meet the most basic requirements (c_1) to access a credit, that is, $S^* < c_1$. Their basic requirements might refer to transaction costs such as application fees or paperwork among others. Farmers who meet the minimum endowments requirements and therefore decide to apply for credit ($S^* > c_1$) may not fulfill further financial institution requirements ($S^* < c_2$), which should in turn lead to credit refusal. These minimum requirements may be related to expected revenue flows, minimum collateral and the like. We denote these farmers as Medium Credit Constrained (**MCC**). Finally, we have those farmers who applied for credit ($S^* > c_1$) and got it ($S^* > c_2$). Among them, some may have gotten the capital at very convenient financial conditions, while others, may have had to renegotiate theirs to less convenient conditions. Given that we do not observe farmers' specific credit conditions this group is not necessarily fully unconstrained, so we label it as Low Credit Constrained (**LCC**).

Figure 1 illustrates this taxonomy using variables that are available in Burkina Faso's household survey. We argue that these three categories relate to alternative information asymmetry mechanisms as highlighted by Boucher et al. (2009). The HCC group is likely to derive from both the transaction-cost and risk rationing mechanisms as it includes farmers that do not apply for a credit because of terms and conditions. The MCC group entails the quantity-rationing mechanism given that they applied for a credit that got refused. Finally, we consider that the LCC group may face quantity-rationing to some extent, as some farmers within this group may have been supplied credit conditions that are less convenient than their original request (demand) i.e. they have borrowed less and/or more expensive capital than originally requested.Since credit constraints on farmers who do not need credit are typically not the focus of policy interventions, we exclude them from our analysis.

Figure 1: Different types of credit constraint based on individual-level questions



Gender and welfare

Access to credit can help smooth household consumption over time in the case of income fluctuation due to negative shocks. However, the impact of credit access on household consumption could change depending on the gender of the household income contributor. For instance, Bhupal and Sam (2014) and Pitt and Khandker (1998) found that female income significantly increases household consumption, especially the share of children's clothing and footwear consumption. Pahl (1990) suggests that men contribute more to the domestic economy than women do in absolute terms, but women contribute a higher proportion of their income in relative terms. Furthermore, women empowerment may play a moderating role on credit's final use. Women tend to have limited control over their loans due to limited rights over productive resources in particular, land and productive assets (Goetz and Gupta, 1996). The bargaining power within household also plays a significant role. In societies where gender norms are very unequal (gendered institutions), more access to and control over individual resources often lowers women's bargaining outcome (Mabsout and van Staveren, 2010). Garikipati (2008) shows that loans procured by women are often used to enhance their husband ownership on household's productive assets.

The agricultural productivity channel

One channel by which credit constraint impacts household welfare in rural areas is agricultural productivity. Many studies provide evidence of imperfect risk-sharing within households and inequality of access to the same technology and the same quality of inputs between men and women (Morrison, 2007; Dercon and Krishnan, 2000; Duflo and Udry, 2003; Dubois and Ligon, 2009). Given that women have smaller initial endowments and technical knowledge, credit access is a main source of capital that could help them improve their productivity.

Farmers may apply for credit for reasons other than to purchase agriculture inputs. While some of them may request credit to develop an existing business or purchase equipment, others might do so to fund education or health expenditures, or rather, festival expenditures. In order to account for this heterogeneity in farmers' motives for applying for credit, we estimate alternative econometric models . The first model includes all observations, regardless of the motives for applying for credit. The second model includes farmers who request credit to purchase productive equipment (be it agricultural or not) or agriculture inputs. The third model includes only farmers who have contracted credit to purchase agricultural inputs.

4 Econometric model

In this section, we discuss the empirical approach for examining the impact of credit constraints on farmers' welfare through the agricultural productivity channel. The proposed specification controls for gender heterogeneity and deals with endogeneity and self-selection concerns. The econometric model may be described as a multinomial endogenous switching regression model.

Model specification

To model the effects of credit constraints on the welfare and productivity of household farmers in need of credit, the econometric specification must address the potential endogeneity or selection bias that results from farmers assignment into alternative credit constraints levels. The presence of unobservables such as unobserved abilities and endowments may simultaneously ease credit constraints and enhance welfare and productivity. As mentioned earlier, the model must also account for three constraint levels (R): LCC (0), MCC (1) and HCC (2).

The i-th farmer endowment (S_i^*) is assumed to be a latent function of x_i, a vector of individual characteristics (age, gender, education, relationship to the household head, etc.), household head socio-demographic characteristics (age, gender, education, etc.) and plot characteristics (type of soil, protection mode, type of relief, plot distance from the farmer's home):

$$S_i^* = \tilde{\beta}' \tilde{x}_i + \mu_i \tag{4.0}$$

where $\tilde{x}$ is a vector of exogenous variables that includes a vector of exclusion restrictions (z_i) that determine selection for a credit constraint regime and have no effect on our outcomes of interest: $\tilde{x}_i' = [x_i' \; z_i']$. The choice of exclusion restrictions is discussed at the end of this section. Unobservable characteristics are denoted by the random term μ_i. Thus, a farmer is mapped to a given credit constraint level (R) according their endowment S_i^* and minimum credit requirements (c_1 and c_2). Similarly, our outcomes of interest (household consumption or farm productivity) at the r-th credit constraint C_{ir} depend on exogenous characteristics x_i and unobservables (ϵ_{ir}) that might correlate with endowments' unobserved determinants (μ_i). Since we observe only farmers of a given constraint level, we get a system of mutually exclusive regimes:

$$C_i = \begin{cases} C_{i0} = \gamma_0' x_i + \epsilon_{i1} & \text{if } S_i^* > c_2 \\ C_{i1} = \gamma_1' x_i + \epsilon_{i2} & \text{if } c_1 < S_i^* < c_2 \\ C_{i2} = \gamma_2' x_i + \epsilon_{i3} & \text{if } S_i^* < c_1 \end{cases} \tag{4.0}$$

This specification can be described as a three-regime endogenous switching regression model. It results from the generalization of the endogenous switching regression model specified in the work of Maddala and Nelson (1975). It can also be described as a multinomial tobit model (Lee, 1993). By assuming a multivariate normal distribution of the vector $[\epsilon_{i1} \; \epsilon_{i2} \; \epsilon_{i3} \; u_i]$, the model's two sets of equations, selection and main outcomes, can be estimated by a full-information maximum likelihood (FIML) approach. Because the regimes are mutually exclusive, the correlations between ϵ_{ir} and $\epsilon_{ir'}$ are not defined. The endogenous sorting into a given credit constraint level leads to a positive correlation between ϵ_{ir} and μ_i as the unobserved skills having a direct positive effect on welfare (household consumption) are also expected to positively affect farmers' endowments (S^*).

Although the model's non-linearities ensure the theoretical identification of the FIML parameters (Lokshin and Sajaia, 2004), the presence of exclusion restrictions may enhance identification of the estimated parameters. The literature provides more parsimonious two-step methods that allow for the estimation of each regime's equation individually, but these are known to be not fully efficient (Lokshin and Sajaia, 2004) so we estimate our model by FIML using STATA (Roodman, 2011).

Farmers that do not need credit do not belong to the population of interest of the econometric model presented above. The model assumes that unobservables that determine the need for credit do not determine neither our main outcomes nor the selection into a given constraint level. To control for a potential source of bias, in case this assumption does not hold, we introduce an additional probit equation that models the need for credit, thus allowing a full econometric specification for our sample of farmers depicted in Figure 1. Appendix C provides further details on the specification of the implied multivariate normal distribution employed in this FIML estimation. For the sake of presentation, we chose to present results from this model, only when it provides estimates that suggest the presence of a sample selection bias. More specifically, our welfare econometric model is estimated following this correction whereas the agricultural yields models presents a standard switching regression model estimated without this correction.

Conditional expectations and treatment effects

Following Chiburis and Lokshin (2007) , we define conditional expectations and treatment effects under the r-th regime given the j-th subpopulation as follows:

$$E(C_{ir}|x_i, R_i = j, x_i, z_i) = x_i'\gamma_r + \rho_r\sigma_r\lambda_{ij} \tag{4.1}$$

Given our three-regimes econometric model, the j-th regime counterfactual correction term λ_{ij} is defined as :

$$
\begin{aligned}
\lambda_{i0} &= -\frac{\phi(c_1 - \tilde{\beta}'\tilde{x}_i)}{\Phi(c_1 - \tilde{\beta}'\tilde{x}_i)} \\
\lambda_{i1} &= \frac{\phi(c_1 - \tilde{\beta}'\tilde{x}_i) - \phi(c_2 - \tilde{\beta}'\tilde{x}_i)}{\Phi(c_2 - \tilde{\beta}'\tilde{x}_i) - \Phi(c_1 - \tilde{\beta}'\tilde{x}_i)} \qquad (4.1) \\
\lambda_{i2} &= \frac{\phi(c_2 - \tilde{\beta}'\tilde{x}_i)}{1 - \Phi(c_2 - \tilde{\beta}'\tilde{x}_i)}
\end{aligned}
$$

where $\phi()$ and $\Phi()$ denote the normal density and cumulative distribution functions, respectively. The r-th regime error term (ϵ_r) variance is denoted by σ_r^2, whereas ρ_r represents its correlation with the unobserved endowments.

In order to identify how credit recipients - the LCC - have benefited from access to credit we define two treatment effects on the treated (ATET). In the first one, we compare LCC farmers' consumption with their counterfactual had they been refused their credits (MCC):

$$
ATET_{MCC \to LCC} = C_{0,i} - E(C_{1i}|x_i, R_i = 0, z_i), \qquad (4.1)
$$

where $C_{0,i}$ is consumption per capita (in log scale) of the i-th LCC individual. The second term on the right-hand side denotes the expected consumption of the same subpopulation (LCC or R=0) had they been medium credit constrained (MCC). This effect is interpreted the ex-post improvement after having received a credit (LCC) with respect to a medium credit constraint (MCC) level.

In the second, we compare the LCC farmers consumption with their conterfactual, had they self-selected out of the credit market (HCC). Similarly, the welfare improvement of the LCC (R=0) sample with respect to their HCC (R=2) counterfactual is denoted by $ATET_{HCC \to LCC}$ and defined as:

$$
ATET_{HCC \to LCC} = C_{0,i} - E(C_{2i}|x_i, R_i = 0, z_i) \qquad (4.2)
$$

These two ATET expressions make it possible to identify the ex-post welfare improvements for the LCC with respect to two more severe credit constraint levels, HCC and MCC. We should recall that welfare improvements from the latter regimes would be indistinguishable under a traditional approach that considers credit access as binary status.

In a similar way, we calculate the average treatment effects on the untreated (ATU) as a means of estimating the benefits of potential interventions on the credit constrained subpopulations. Specifcally, we choose to assess the ATU for the MCC and HCC populations, had they be low credit constrained (LCC). In order to assess the gender effects on welfare and productivity, we estimate gender specific switching regressions and their corresponding ATET and ATU.

Identification strategy

Even though empirical identification can be achieved through the model's non-linearities, we improve it by introducing exclusion restrictions (z_i). Following Ali et al. (2014), we argue that social networks may improve households' access to information and thus access to credit. In practice, the z_i vector includes three indicators related to a household's social networks and access to information.

The first indicator is the number of household members who are part of an association. The greater the number of people in a household who are members of an association, the greater the probability that the household has access to information about accessing credit. The second indicator is the number of household members who are members of a decision-making body of an association. Because this indicator refers to a decision-making body, it may be a better proxy of access to credit information through an association. The third indicator is the proportion of households in the department[2] that have a person who is a member of an association. Even though this is a regional indicator, it is computed at the household level as the ratio of the number of households that include (at least) one member of an association, excluding the current household, to the total number of households in the department, minus the current household. This instrument measures the potential that a given household access credit information from its neighbors (department).

It may be easily argued that unobservable characteristics such as unobserved skills may affect both household consumption and access to credit, leading to an endogenous credit constraint status. On one hand, farmers may be sorted on gains by credit institutions, meaning the most productive are more likely to be

[2] Burkina Faso's provinces are divided in 351 departments or "communes."

granted access to credit. On the other hand, more skilled farmers are expected to procure themselves higher levels of well-being irrespective of their credit constraint status. In the context of an instrumental variable (IV) estimation, our exclusion restrictions can be interpreted as instruments that are expected to be correlated to the credit constraint indicator but should not be correlated to consumption (orthogonality assumption). To explore the validity of the latter assumption, we estimate an auxiliary model where credit constraints (R) enter the consumption equation as a continuous regressor. This makes it possible to test the validity of our exclusion restrictions in terms of their weakness (correlation with the endogenous regressor), but most importantly, in terms of their orthogonality with respect to the main equation residual term. We implement the more efficient GMM IV estimator available in Stata's IVREG2 and perform the overidentification exclusion test.

Data and descriptive statistics

We use data from Burkina Faso's MICS 2014. MICS is a nationally representative survey that includes information from both the household and the individual level. In total, 10,800 households were surveyed. In addressing this study's research question, the study sample was restricted to agricultural households representing 7,410 households overall. MICS 2014 collected detailed information about agricultural activity such as production, the use of inputs and plot characteristics. The survey also includes a detailed module on household consumption and other sections on household characteristics, the socio-demographic characteristics of members, credit and savings, etc.

The less constrained farmers are, the more capital they have

Table 1 presents the socio-demographic characteristics of farmers and landowners by credit constraint status. It appears that MCC and LCC farmers are different from HCC farmers in many ways. In terms of socio-demographic characteristics, LCC and MCC farmers are likely to be younger, male and married. Furthermore, they appear to have access to larger social networks than their HCC peers. The proportion of MCC or LCC farmers who have a member of an association in their household is higher than that of HCC farmers. Furthermore, LCC farmers seem wealthier and more endowed in terms of human capital compared to the other two farmer groups, while MCC and HCC farmers don't seem different regarding their average consumption per capita or their education. These relationships are consistent with the intuition that the more capital farmers have, the less they are financially constrained.

Moreover, it is worth noting differences in the characteristics of farmers and landowners, suggesting that farmers don't systematically own the plots they work. While farmers and landowners may seem to have on average the same level of education and a similar likelihood of having a member of an association or a decision-making body of an association in their household, they are different in terms of age, sex and link to the household head. Landowners are more likely to be older, male and household heads. In fact, regardless the level of credit constraint, land owners are mostly male, household heads and relatively older compared to farmers. This points to unequal access to land ownership, with female and younger farmers being worse off.

Plot characteristics, management mode and input use are different between the three groups

The fact that MCC and LCC farmers are better off might be explained by differences in the farming practices and type of inputs used in the plots (Table D1). Both MCC and HCC farmers tend to manage their plots collectively, while LCC farmers adopt a more individual management mode. This suggests that MCC and HCC farmers tend to pool their resources to maximize their output and share the various economic risks.

Furthermore, MCC and LCC farmers seem to have more access to better inputs than HCC farmers. The latter use more garbage as fertilizer on average, whereas MCC and LCC farmers use more chemical fertilizers and phytosanitary products. HCC farmers are also less likely to use storage techniques compared to their MCC and LCC peers. The cost of these inputs may explain their high use by MCC and LCC farmers, as they appear to be wealthier compared to HCC farmers.

Plot characteristics by gender

The same patterns are observed when the sample is broken down into male and female farmers. The management mode of male and female farmers appears generally similar to the overall pattern (Table D1). LCC male and female farmers are likely to manage their plot individually, whereas their HCC and MCC counterparts adopt collective management practices. We observe also that LCC male and female farmers are likely to use chemical phytosanitary products as inputs. In addition, LCC farmers seem to have more access to better inputs and use more storage techniques than HCC farmers regardless of gender. This suggests that the cost of inputs may represent an important constraint that doesn't depend on gender. Both female and male HCC farmers may not have enough resources to access better inputs.

Table 1: Socio-demographic characteristics of farmers and landowners by credit constraint status

	High			Medium			Low			Medium - High		Low - High	
	Mean	Sd	Obs.	Mean	Sd	Obs.	Mean	Sd	Obs.	Mean	t-stat	Mean	t-stat
Farmer characteristics													
Socio-demographic characteristics													
Age	46.0	16.3	3613	43.0	14.8	1435	44.4	13.2	1578	-3.0	-6.4***	-1.6	-3.8***
Female	0.4	0.5	3613	0.3	0.5	1435	0.2	0.4	1578	0.0	-1.3	-0.2	-16.2***
Married	0.9	0.3	3610	0.9	0.3	1434	0.9	0.3	1577	0.0	3.1***	0.1	6.3***
Link with household head													
Head	0.7	0.5	3613	0.7	0.5	1435	0.9	0.3	1578	-0.02	-1.6*	0.2	-1.6*
Spouse of the head	0.2	0.4	3613	0.2	0.4	1435	0.1	0.2	1578	0.0	0.8	-0.1	0.8
Other	0.1	0.3	3613	0.1	0.3	1435	0.0	0.1	1578	0.0	1.4	-0.1	1.4
Education													
No education	0.9	0.3	3582	0.9	0.3	1423	0.9	0.3	1554	0.0	1.8*	0.0	-1.6*
Primary	0.1	0.3	3582	0.1	0.2	1423	0.1	0.3	1554	0.0	-2.2**	0.0	0.9
Secondary and higher	0.0	0.2	3582	0.0	0.2	1423	0.0	0.2	1554	0.0	0.2	0.0	1.5
Social networks													
Association membership (YES)	0.2	0.4	3586	0.2	0.4	1433	0.4	0.5	1574	0.0	1.4	0.2	12.9***
Decision-making body of an association (YES)	0.3	0.5	726	0.3	0.4	325	0.4	0.5	603	-0.1	-1.7*	0.1	2.6***
Land owner characteristics													
Socio-demographic characteristics													
Age	48.6	16.2	2354	46.8	14.8	837	45.0	13.2	1142	-1.8	-3.0***	-3.6	-7.1***
Female	0.2	0.4	2354	0.1	0.4	837	0.1	0.3	1142	-0.1	-6.0***	-0.1	-10.0***
Married	0.9	0.3	2354	0.9	0.3	836	0.9	0.3	1141	0.0	1.9**	0.0	3.9***
Link with household head													
Head	0.8	0.4	2354	0.9	0.3	837	1.0	0.2	1142	0.1	4.7***	0.1	13.0***
Spouse of the head	0.1	0.3	2354	0.1	0.2	837	0.0	0.2	1142	-0.1	-4.8***	-0.1	-11.1***
Other	0.0	0.2	2354	0.0	0.2	837	0.0	0.1	1142	0.0	-1.2	0.0	-6.2***
Education													
No education	0.9	0.3	2333	0.9	0.3	834	0.9	0.3	1126	0.0	2.2**	0.0	-0.3
Primary	0.1	0.3	2333	0.1	0.2	834	0.1	0.3	1126	0.0	-2.8***	0.0	0.6

Table 1 (continued) Socio-demographic characteristics of farmers and landowners by credit constraint status

	High			Medium			Low			Medium - High		Low - Medium	
	Mean	Sd	Obs.	Mean	Sd	Obs.	Mean	Sd	Obs.	Mean	t-stat	Mean	t-stat
Secondary and higher	0.0	0.2	2333	0.0	0.2	834	0.0	0.1	1126	0.0	0.4	0.0	-0.5
Social networks													
Association membership (YES)	0.2	0.4	2347	0.2	0.4	837	0.4	0.5	1139	0.0	1.7*	0.2	10.8***
Association membership (% district population)	0.2	0.30	3611	0.2	0.30	1435	0.30	0.35	1578	.0	1.1	0.1	10.7***
Decision-making body of an association (YES)	0.3	0.5	485	0.3	0.5	205	0.4	0.5	445	0.0	-0.7	0.1	2.4**
Household welfare													
Deflated consumption per capita (thousands FCFA)	190.4	105.8	3613	193.5	106.7	1435	217.8	122.5	1578	3.1	0.9	27.4	7.7***
Poverty incidence	0.4	0.5	3613	0.4	0.5	1435	0.4	0.5	1578	0.0	-0.7	-0.1	-6.6***

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

Source: EMC 2014, Agricultural household sample, authors' calculations

5 Results

In this section, we first test the validity of our exclusion restrictions within an IV estimation framework. We then present and discuss the results of the multinomial switching regression model in light of the channels that drive the relationship between credit constraints and household welfare.

Social networks as a proper exclusion restriction

Even though our main model is non-linear, we implement a linear version of it by requiring the credit constraint indicator to be continuous. This makes it possible to test our exclusion restrictions as if they were instrumental variables. More specifically, we test their weakness and orthogonality conditions. Once tested, the exclusion restrictions (z_i) are included in the definitive non-linear multinomial switching regression model.

Table D2 presents the diagnostic test results of our IV (GMM) estimator where the household consumption equation is a function of a continuous credit constraint endogenous regressor. Given that we have three instruments, we can test for orthogonality between our chosen instruments and the main equation residual term. The implied Hansen test does not reject the null of orthogonality, which confirms that the IV estimator is likely to be asymptotically consistent in the presence of the potential endogeneity of the credit constraint with respect to our welfare outcome. This supports the weak exogeneity of our exclusion restrictions, which we introduce to improve the empirical identification of the multinomial switching regression model.

An IV estimator could be biased in the presence of a weak relationship between the endogenous regressor and our instruments. Table D2 shows a significant positive correlation between the instruments and the credit constraint indicator. A formal test is provided by the Cragg-Donald F statistic that suggests that our instruments are not weak compared to Stock-Yogo weak identification critical values (Table D2). This verifies the social capital argument that having a person in the household who is a member of an association or living in a district where there are many associations helps farmers improve their access to credit.

The effects of credit constraints on household welfare

Table 2 presents the estimated welfare's average treatment effects (ATET and ATU) of the different credit constraint levels by gender. Whereas the ATET is informative of ex-post welfare improvement, the ATU is informative of ex-ante potential improvement, i.e., while the former assesses the outcome of an observed intervention on a treated subpopulation, the latter assesses the potential improvement that would result from a policy intervention on an untreated subpopulation. Recall that with a traditional binary indicator of access to credit, those unable to obtain credit - the HCC and MCC - would be confounded together, implying a potential loss of information. To assess whether a more parsimonious binary approach should be preferred to our three-tiered approach to credit constraints, we compare the consumption and productivity improvements resulting from a transition from HCC to LCC versus a transition from MCC to LCC. If these two are statistically similar, then a binary approach should be preferred.

Table 2 (Panel A) shows a gender decomposition of the ATET that suggests that women have benefited the most from access to credit. The pairwise comparison between low credit constrained with respect to counterfactual medium and high constrained status confirms that not having access to credit implies different levels of household consumption. Specifically, low constrained men farmers benefited on average of a 6 and 9 per cent increase in household consumption vis-a-vis their medium and high constrained counterfactuals respectively. Women exhibit higher benefits from access to credit, 31 and 54 percent with regards to their medium and highly constrained counterfactuals. This provides evidence of the non-negligible heterogeneity among credit non-recepients (HCC and MCC), thus favouring a three-tiered approach with regards a binary one.

In order to identify the potential (ex-ante) improvements in credit constrained subpopulations, we present ATU(s) estimates on Table 2 (Panel B). Men's ATU(s) stay in line with their ATET(s) as the potential improvement of medium and highly constrained farmers would be 4 and 11 per cent with regards to their low constraint counterfactual. In other words, a hypothetical intervention that pushes men farmers from HCC to LCC status is expected to improve welfare by about 11 per cent. The potential gains among medium and highly constrained women stay important, 11 and 13 per cent respectively with respect to their low constraint status.

Even though men's ATET(s) and ATU(s) tend to be similar, which may occur when the assignment into different treatment levels is random, the empirical inequality between women's ATET(s) and ATU(s) provides evidence of the validity of our switching regression framework to model the assignment into alternative credit constraint levels. It should be noticed that the multinomial switching regression model behind Table 2, required the inclusion of an additional equation to model the selection into need for credit (see appendix C). This can be verified by comparing the standard and the corrected treatment effects from Tables (D6) and (2) respectively. Most notably, is the implausibility of women's ATET(s) under the standard (uncorrected) model: The improvement from a medium to a low constraint level (15 percent) is larger than the improvement from a high to low constraint status (9 per cent).

The underlying estimating equations behind Table 2 verify some stylized facts (see Table D4). As expected, education improves farmer's human capital and therefore consumption per capita across the three regimes. However, such improvement is less pronounced in the case of women, who get positive returns only on primary education. It should be noticed that from our credit constraint ordinal scale, the ordered probit linear predictor presented in Table (D4) relates negatively to the implied endowments (S^*). Our exclusion restrictions, which are a proxy of available social networks, exhibit statistically significant negative coefficients, that is, social networks relate positively to farmers' endowments.

The agricultural productivity channel

Welfare improvements due to productive credit constraint relaxation are expected to be channeled through agricultural productivity enhancements. To examine the impact of credit constraints on agricultural yield, our empirical analysis builds on the endogenous switching regression model using the log of agricultural productivity as the main outcome instead of consumption.

Agricultural productivity is measured by production per hectare (yield) which we standardise to the survey sample mean for each crop.. This implies that our standardized yield indicator has an average value of one irrespective of the type of crop. In Burkina Faso, male and female farmers do not grow the same types of crops. Men usually plant cereals such as maize, millet and rice, whereas women

Table 2: Treatment effects of credit constraints on the consumption per capita (log scale) by farmer gender

Sample	**Categories**	**Obs.**	**Treated/ Untreated (1)**	**Counterfactual (2)**	**Diff. (1) - (2)**	**t-stat**
Panel A: Average Treatment on the Treated (ATET)						
Men	Low (Treated) VS Medium (Counterfactual)	1311	12.17 (0.47)	12.11 (0.21)	0.06***	5.23
	Low (Treated) VS High (Counterfactual)	1311	12.17 (0.47)	12.08 (0.25)	0.09***	7.62
Women	Low (Treated) VS Medium (Counterfactual)	257	12.18 (0.51)	11.87 (0.16)	0.31***	10.52
	Low (Treated) VS High (Counterfactual)	257	12.18 (0.51)	11.64 (0.23)	0.54***	19.06
Panel B: Average Treatment on the Untreated (ATU)						
Men	Low (Counterfactual) VS Medium (Untreated)	937	12.15 (0.25)	12.11 (0.46)	0.04***	3.09
	Low (Counterfactual) VS High (Untreated)	2289	12.15 (0.22)	12.04 (0.47)	0.11***	12.35
Women	Low (Counterfactual) VS Medium (Untreated)	491	12.09 (0.33)	11.98 (0.40)	0.11***	5.86
	Low (Counterfactual) VS High (Untreated)	1306	12.17 (0.28)	12.04 (0.46)	0.13***	10.70

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

plant market gardening or cash crops such as vegetables, peanuts and beans. Thus, we define two yield indicators that are specific to male and female farmers. An exploratory analysis showed the presence of outlying observations for this indicator; we chose to deal with extreme yields by identifying those that lie above the maximum yields per type of crop set by the DGPER. Once identified, the extreme yields are truncated to the maximum provided for by the DGPER[3]. Furthermore, crops with fewer than 30 observations in our sample are dropped from the analysis.

Regarding men's yield effects for both crops, in Table 3 we identify positive yield effects of credit constraint relaxation when transitioning from HCC to LCC and from MCC to LCC status from both, ex-post (ATET) and ex-ante potential interventions (ATU). As expected, productivity enhancements from a highly constrained status are larger than the ones from a medium constrained status. More specifically, credit access would improve highly and medium constrained men farmers' productivity in 150 (162) and 78 (77) per cent respectively, according to their ATET (ATU). Qualitatively, women exhibit a similar outlook than men, as credit access would improve highly and medium constrained women farmers in 151 (133) and 58 (68) per cent respectively, according to their ATET (ATU). Although these findings alone, support the transmission channel from credit access to welfare, we further explore women's results since these may be sensitive to their empowerment context as has been suggested by the literature (Garikipati, 2008; Goetz and Gupta, 1996).

Women farmers empowerment and productivity

To further explore women productivity effects, we bring into our database information regarding women empowerment at the regional level obtained from 2014's DHS survey. We build a regional women empowerment indicator following DHS's definition, i.e., as the percentage of currently married women within a region (aged 15-49) who participate in all decisions making processes. Three dimensions are considered, decisions regarding respondent's health care, decisions regarding large household purchases and decisions about the visits to family or relatives. We split our sample into high and low women empowerment regions in order estimate their corresponding productivity ATET(s) and ATU(s). From the intersection of our original data and DHS survey, we identify 13 regions among

[3] The DGPER is a government institution that works to promote agricultural activities and local agricultural products.

Table 3: Treatment effects of credit constraints on plot standardized yields (log scale) by gender

Sample	Categories	Obs.	Treated/ Untreated (1)	Counterfactual (2)	Diff. (1) - (2)	t-stat
Panel A: Average Treatment on the Treated (ATET)						
Men	Low (Treated) VS Medium (Counterfactual)	3642	1.08 (1.23)	0.30 (0.27)	0.78***	37.62
	Low (Treated) VS High (Counterfactual)	3642	1.08 (1.23)	-0.42 (0.26)	1.50***	72.03
Women	Low (Treated) VS Medium (Counterfactual)	493	0.88 (1.23)	0.30 (0.29)	0.58***	11.43
	Low (Treated) VS High (Counterfactual)	493	0.88 (1.07)	-0.64 (0.23)	1.51***	31.24
Panel B: Average Treatment on the Untreated (ATU)						
Men	Low (Counterfactual) VS Medium (Untreated)	2599	1.73 (0.26)	0.96 (1.21)	0.77***	32.15
	Low (Counterfactual) VS High (Untreated)	6430	2.59 (0.20)	0.98 (1.25)	1.62***	103.18
Women	Low (Counterfactual) VS Medium (Untreated)	514	1.58 (0.49)	0.90 (1.15)	0.68***	12.38
	Low (Counterfactual) VS High (Untreated)	1604	2.28 (0.37)	0.95 (1.31)	1.33***	39.53

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

which 4 had above average women empowerment regional indicators and 9 were below average. Since women empowerment may be determined by unobservable individual and household characteristics linked to our outcomes of interest and farmers' unobservable endowments (μ_i), we do not claim these estimates to be interpreted as causal effects. They are presented as a formal approach to test for the presence of alternative mechanisms documented in the literature, linked to the moderating role of women empowerment. Table 4 presents these estimates. Interestingly, the ATET and ATU estimated at low empowerment regions yields a negative effect whereas in the high empowerment regions our effects remain positive. We should recall that our sample of farmers declared to have asked for credit for agricultural production purposes, thus, the negative effects on productivity on less empowered regions support the presence of alternative mechanisms, such as credit diversion.

Table 4: Treatment effects of credit constraints on plot standardized yields (log scale) managed by female farmer

Sample	**Categories**	**Obs.**	**Treated/ Untreated (1)**	**Counterfactual (2)**	**Diff. (1) - (2)**	**t-stat**
	Panel A: Average Treatment on the Treated (ATET)					
Low empowerment	Low (Treated) VS Medium (Counterfactual)	326	0.53 (0.43)	0.60 (0.12)	-0.07***	-2.90
	Low (Treated) VS High (Counterfactual)	326	0.53 (0.43)	0.73 (0.08)	-0.21***	-8.57
High empowerment	Low (Treated) VS Medium (Counterfactual)	167	0.51 (0.42)	0.28 (0.11)	0.23***	7.01
	Low (Treated) VS High (Counterfactual)	167	0.51 (0.42)	-0.01 (0.14)	0.52***	15.93
	Panel B: Average Treatment on the Untreated (ATU)					
Low empowerment	Low (Counterfactual) VS Medium (Untreated)	356	0.45 (0.15)	0.52 (0.43)	-0.06***	-2.56
	Low (Counterfactual) VS High (Untreated)	919	0.36 (0.15)	0.52 (0.43)	-0.21***	-14.15
High empowerment	Low (Counterfactual) VS Medium (Untreated)	158	0.92 (0.34)	0.56 (0.46)	0.37***	8.74
	Low (Counterfactual) VS High (Untreated)	685	1.14 (0.30)	0.51 (0.44)	0.63***	32.41

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In rural areas, non-farm income could relieve liquidity constraints for households that engage in multiple activities (Haider et al., 2018). Women from indebted households could divert the credit towards more productive business activities to ensure loan repayment. This change in women's behavior might occur due to imperfect risk sharing within the household (Dercon and Krishnan, 2000; Duflo and Udry, 2003; Dubois and Ligon, 2009; Kazianga and Wahhaj, 2013). Because women have low bargaining power in the household, they are not fully empowered to decide how their credit should be used. They may witness a misappropriation of their credit for other purposes. In addition, inefficiency in the allocation of productive resources within the household (Udry, 1996; Goldstein and Udry, 2008b) may not allow them to use other resources that are available so as to use their credit more efficiently.

Credit diversion has not been widely documented in the literature, most likely because of methodological challenges involved in formally measuring it (Feder et al., 1990, 1992). Our results support previous findings (Goetz and Gupta, 1996; Banerjee et al., 2015) and contribute to this literature by providing evidence of negative effects on agricultural productivity from women farmers residing in regions characterized by a low women empowerment.

6 Concluding remarks

Our findings suggest that easing credit constraints results overall in significant household welfare improvement irrespective of farmers' gender. More specifically, ATET estimates suggest that the improvement in the welfare of women farmers is higher than that of men. Even though our analysis of the effects of the relaxation of credit constraints on agricultural productivity shows that men and women significantly improve their agricultural productivity, it does not verify that women improve the most. Given the gender disparities in land property rights that favor men in Burkina Faso, we test for the presence of women empowerment related factors that could moderate or disrupt the transmission channel between credit access and welfare through productivity. Hence, we split our main sample in two sub-samples that can be characterized of high and low empowerment. Sub-sample specific analyses confirm that women farmers in low empowerment regions not only do not improve their productivity, but also reduce it. We argue that this could be explained by a diversion of credit to alternative assets or consumer spending, or both, which in turn could explain the seemingly implausible consumption ATET reported in Table 2. Our conjecture is in line with previous findings by which women's disempowerment is related to credit diversion in a context of weak property rights. As Garikipati (2008) argued in her study of a lending program in India, women's lack of co-ownership, combined with credit diversion practices, probably led to women's disempowerment.

The informativeness of our three-tiered credit constraint approach relative to a binary one is verified by the larger estimated treatment effects (ATET and ATU) of a transition from a high credit constraint to a low credit constraint state versus a transition from a medium to a low credit constraint state. Policy-wise, an intervention aiming at granting credit to HCC farmers implies a wide set of policy instruments that should not only aim at improving farmers' endowments ($S^* < c1$), but may also ease the conditions of access to credit (reducing c_1 and c_2). Hence, not surprinsingly, such an ambitious intervention on men's credit constraints is expected to improve their productivity in about 162 per cent (ATU). Similarly, a less ambitious hypothetical intervention seeking to grant access to MCC men farmers would improve their productivity in about 77 per cent. The resulting ATU welfare improvements are estimated to 11 per cent for the HCC and to 4 per cent for the MCC. As mentioned above, gender disparities in property rights appear to disrupt the productivity channel of disempowered women. Hence, a successful intervention only seems feasible for empowered women, whose agricultural productivity improvement (ATU) is estimated at 37 per cent for MCC and 63 per cent for HCC, well below estimates for men.

This study highlights how critical of a role credit constraints may play in designing agricultural policies in Burkina Faso. Easing credit constraints translates into improved welfare for farmers. Yet, increased productivity is likely to be a potential mechanism behind this welfare gain only for male farmers and the share of empowered women. These gender-related differential effects suggest that improved financial inclusion measures should be combined with measures to empower women, such as reducing the gender gap in property rights. A lack of bargaining power and capital constraints (education, land, etc.) represent potential factors that prevent female farmers from making the most of the advantage credit provides for their agricultural activities. Consequently, tackling these obstacles must be considered, and policies that combine access to credit and measures to empower female farmers might be necessary to close the gender-related productivity gap in Burkina Faso.

References

Akresh, Richard, "Understanding Pareto inefficient intrahousehold allocations," 2005.

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein, "Environmental and gender impacts of land tenure regularization in Africa: Pilot evidence from Rwanda," *Journal of Development Economics*, 2014, *110*, 262–275.

Banerjee, Tanmoyee, Malabika Roy, Ajitava Raychaudhuri, and Chandralekha Ghosh, "What drives households to divert loans? A village level study," *Asia-Pacific Social Science Review*, 2015, *15* (2), 33–55.

Bhupal, G. and A.G. Sam, "Female income and expenditure on children: Impact of the national rural employment guarantee scheme in India," *Applied Econometrics and International Development*, January 2014, *14*, 175–192.

Boucher, Stephen R., Catherine Guirkinger, and Carolina Trivelli, "Direct elicitation of credit constraints: Conceptual and practical issues with an application to Peruvian agriculture," *Economic development and cultural change*, 2009, *57* (4), 609–640. Publisher: The University of Chicago Press.

Chiburis, Richard and Michael Lokshin, "Maximum likelihood and two-step estimation of an ordered-probit selection model," *The Stata Journal*, 2007, *7* (2), 167–182.

Christiaensen, Luc, Lionel Demery, and Jesper Kuhl, "The (evolving) role of agriculture in poverty reduction—An empirical perspective," *Journal of Development Economics*, November 2011, *96* (2), 239–254.

Combary, Omer S and Kimseyinga Savadogo, "The Sources of Total Factor Productivity Growth in Burkina Faso's Cotton Farms," *Revue d'économie du développement*, 2014, *22* (4), 61–82.

Croppenstedt, Andre, Markus Goldstein, and Nina Rosas, "Gender and Agriculture: Inefficiencies, Segregation, and Low Productivity Traps," *The World Bank Research Observer*, 2013, *28* (1), 79–109. Publisher: Oxford University Press.

de Janvry, Alain and Elisabeth Sadoulet, "Agricultural Growth and Poverty Reduction: Additional Evidence," *The World Bank Research Observer*, February 2010, *25* (1), 1–20.

Dercon, Stefan and Pramila Krishnan, "In Sickness and in Health: Risk Sharing within Households in Rural Ethiopia," *Journal of Political Economy*, August 2000, *108* (4), 688–727. Publisher: The University of Chicago Press.

Dubois, Pierre and Ethan A. Ligon, "Nutrition and Risk Sharing within the Household," SSRN Scholarly Paper ID 1533179, Social Science Research Network, Rochester, NY November 2009.

Duflo, Esther and Christopher Udry, "Intrahousehold Resource Allocation in Cote D'Ivoire: Social Norms, Separate Accounts and Consumption Choices," SSRN Scholarly Paper ID 427064, Social Science Research Network, Rochester, NY June 2003.

Feder, Gershon, Lawrence J Lau, Justin Y Lin, and Xiaopeng Luo, "The relationship between credit and productivity in Chinese agriculture: A microeconomic model of disequilibrium," *American Journal of Agricultural Economics*, 1990, *72* (5), 1151–1157.

_ , _ , _ , and _ , "The determinants of farm investment and residential construction in post-reform China," *Economic Development and Cultural Change*, 1992, *41* (1), 1–26.

Food, [FAO] and Agriculture Organization, "Women in agriculture: closing the gender gap for development," 2011.

Garikipati, Supriya, "The impact of lending to women on household vulnerability and women's empowerment: evidence from India," *World development*, 2008, *36* (12), 2620–2642.

Goetz, Anne Marie and Rina Sen Gupta, "Who takes the credit? Gender, power, and control over loan use in rural credit programs in Bangladesh," *World Development*, 1996, *24* (1), 45–63.

Goldstein, Markus and Christopher Udry, "The profits of power: Land rights and agricultural investment in Ghana," *Journal of political Economy*, 2008, *116* (6), 981–1022.

_ and _ , "The Profits of Power: Land Rights and Agricultural Investment in Ghana," *Journal of Political Economy*, 2008, *116* (6), 981–1022. Publisher: The University of Chicago Press.

Grootaert, C, O Gi-taik, and A Swamy, "Social capital and development outcomes in Burkina Faso. Local level institutions study," *World Bank, Washington, DC, mimeo*, 1999.

Haider, Hamza, Melinda Smale, and Veronique Theriault, "Intensification and intrahousehold decisions: Fertilizer adoption in Burkina Faso," *World Development*, May 2018, *105*, 310–320.

Horrell, Sara and Pramila Krishnan, "Poverty and productivity in female-headed households in Zimbabwe," *Journal of Development Studies*, 2007, *43* (8), 1351–1380. Publisher: Taylor & Francis Journals.

Jappelli, Tullio, "Who is credit constrained in the US economy?," *The Quarterly Journal of Economics*, 1990, *105* (1), 219–234. Publisher: JSTOR.

Kazianga, Harounan and William A. Masters, "Investing in soils: field bunds and microcatchments in Burkina Faso," *Environment and Development Economics*, July 2002, *7* (3), 571–591. Publisher: Cambridge University Press.

_ **and Zaki Wahhaj**, "Gender, Social Norms, and Household Production in Burkina Faso," *Economic Development and Cultural Change*, 2013, *61* (3), 539–576. Publisher: The University of Chicago Press.

Kuntchev, Veselin, Rita Ramalho, Jorge Rodríguez-Meza, and Judy S Yang, "What have we learned from the Enterprise Surveys regarding access to finance by SMEs," *Enterprise Analysis Unit of the Finance and Private Sector Development, The World Bank Group*, 2012.

Lee, Lung-Fei, "6 Multivariate tobit models in econometrics," in "Econometrics," Vol. 11 of Handbook of Statistics, Elsevier, 1993, pp. 145 – 173.

Lokshin, Michael and Zurab Sajaia, "Maximum likelihood estimation of endogenous switching regression models," *The Stata Journal*, 2004, *4* (3), 282–289.

Mabsout, Ramzi and Irene van Staveren, "Disentangling Bargaining Power from Individual and Household Level to Institutions: Evidence on Women's Position in Ethiopia," *World Development*, 2010, *38* (5), 783–796.

Maddala, G.S. and Forrest D Nelson, "Specification Errors in Limited Dependent Variable Models," Working Paper 96, National Bureau of Economic Research July 1975. Series: Working Paper Series.

Morsy, Hanan, "Access to finance : Mind the gender gap," *The Quarterly Review of Economics and Finance*, 2020, *78*, 12 – 21.

Pahl, Jan, "Household spending, personal spending and the control of money in marriage," *Sociology*, 1990, *24* (1), 119–138. Publisher: Sage Publications, Ltd.

Pitt, Mark M and Shahidur R Khandker, "The impact of group-based credit programs on poor households in Bangladesh: Does the gender of participants matter?," *Journal of political economy*, 1998, *106* (5), 958–996.

Quisumbing, Agnes, "Male-female differences in agricultural productivity: Methodological issues and empirical evidence," *World Development*, 1996, *24* (10), 1579–1595. Publisher: Elsevier.

Roodman, D., "Fitting fully observed recursive mixed-process models with cmp," *Stata Journal*, 2011, *11* (2), 159–206(48).

Sinha, Nistha Andrew Raju Morrison Dhushyanth, *Gender Equality, Poverty And Economic Growth* Policy Research Working Papers, The World Bank, November 2007.

Slavchevska, Vanya, "Gender differences in agricultural productivity: the case of Tanzania," *Agricultural Economics*, 2015, *46* (3), 335–355.

Theriault, Veronique, Melinda Smale, and Hamza Haider, "How Does Gender Affect Sustainable Intensification of Cereal Production in the West African Sahel? Evidence from Burkina Faso," *World Development*, April 2017, *92*, 177–191.

Tiruneh, A., T. Tesfaye, W. M. Mwangi, and H. Verkuijl, *Gender differentials in agricultural production and decision-making among smallholders in Ada, Lume, and Gimbichu Woredas of the central highlands of Ethiopia*, CIMMYT, 2001. Accepted: 2012-01-06T05:09:52Z.

Udry, Christopher, "Gender, Agricultural Production, and the Theory of the Household," *Journal of Political Economy*, 1996, *104* (5), 1010–1046. Publisher: University of Chicago Press.

_ , John Hoddinott, Harold Alderman, and Lawrence Haddad, "Gender differentials in farm productivity: implications for household efficiency and agricultural policy," *Food Policy*, October 1995, *20* (5), 407–423.

wa Gĩthĩnji, Mwangi, Charalampos Konstantinidis, and Andrew Barenberg, "Small and as Productive: Female-headed households and the inverse relationship between land size and output in Kenya.," 2011.

Appendices

A Poverty incidence and credit constraints

Table A.1: Poverty incidence by credit constraint status (%)

	HCC	MCC	LCC	National
Poor	55.4	44.1	51.9	40.1
Not poor	44.6	55.9	48.1	60.9

B Econometric model: further note on error terms

The error terms are assumed to have a quadrivariate normal distribution with zero mean and variance-covariance matrix Σ, i.e, (ϵ_{1i}, ϵ_{2i},ϵ_{3i},μ_i) $N(O, \Sigma)$ with :

$$\Sigma = \begin{bmatrix} \sigma_\mu^2 = 1 & . & . & . \\ \sigma_{1\mu} & \sigma_1^2 & . & . \\ \sigma_{2\mu} & . & \sigma_2^2 & . \\ \sigma_{3\mu} & . & . & \sigma_3^2 \end{bmatrix}$$

where $\sigma_\mu^2 = 1$ is the variance of the error term in the ordered probit that models the selection into the many regimes 4. σ_j^2, are the variances of the error terms in our main outcomes (consumption and yields) and $\sigma_{j\mu}$ represents the covariance between μ_i and ϵ_{ji}. Because y_{ji}, are not observed simultaneously for a farmer, the covariance between ϵ_{ji} are not defined (Maddala, 1983).The error structure implies that the error term μ_i is correlated with the error terms of the consumption functions ϵ_{ji}. We assume that μ and ϵ are standard bivariate normal with correlation ρ, so, the conditional distribution of μ given ϵ_j is normal with mean $\rho_j \epsilon_j$ and variance $1 - \rho_j^2$.

Instead of the two-step procedure (see Maddala, 1983), we use the Full information maximum likelihood estimation to estimate the model (FIML) (Lee and Trost, 1978) (Chiburis and Lokshin, 2007). It consists in finding the parameters β_j, γ_j, c_j, ρ_j, σ_j values that maximize the likelihood of the data. Given the parameters, the likelihood of an observation i in which the category j and y_i is observed :

$$L_{ij}^y = L\left[y_{ji}|x_i, \beta, \gamma_j, \rho_j, \sigma_j, c_j\right] \tag{B.1}$$

$$= L\left[x_i, \gamma_j, \sigma_i\right] Pr[j|y_{ji}, x_i, \beta, \gamma_j, \rho_j, \sigma_i, c_j] \tag{B.2}$$

$$= \frac{1}{\sigma_i}\phi(t_i)\left[\Phi\left(\frac{\beta X_i + \rho_j t_i - c_i}{\sqrt{1-\rho_j^2}}\right) - \Phi\left(\frac{\beta X_i + \rho_j t_i - c_{i+1}}{\sqrt{1-\rho_j^2}}\right)\right] \tag{B.3}$$

Where $t_i = (y_i - \beta_j' x_i)/\sigma_j$, ϕ is the standard normal density function, and Φ is the standard normal cumulative distribution function. The identification of the model requires the exclusion criteria which means the introduction of identifying (or selection) variables Z_i such that $X_i = (W_i, Z_i)$.

C Sample selectivity bias correction

The model presented above builds on a sample of farmers that reported a need for credit, where the sample of farmers that do not need any credit has been dismissed. This multivariate error specification assumes that the unobservables that determine the need for credit do not determine either the outcome of interest (consumption or agricultural yields) and/or the selection into a given credit constraint level. In order to correct for the potential bias caused by a violation to this assumption, an additional probit equation may be introduced to model the selection into our sample of interest, those in need for credit. Thus, our Σ matrix must consider an additional dimension

$$\Sigma = \begin{bmatrix} \sigma_c^2 = 1 & . & . & . & . \\ \sigma_{\mu c}^2 & \sigma_\mu^2 = 1 & . & . & . \\ \sigma_{1c}^2 & \sigma_{1\mu} & \sigma_1^2 & . & . \\ \sigma_{2c}^2 & \sigma_{2\mu} & . & \sigma_2^2 & . \\ \sigma_{3c}^2 & \sigma_{3\mu} & . & . & \sigma_3^2 \end{bmatrix}$$

Where $\sigma_c^2 = 1$ is the variance of the new probit equation and the many σ_{jc}^2 represent the error terms' covariances between the new probit equation and the remaining error terms in our system.

D Statistic tables

Table D1: Plots' characteristics by status of credit constraint

	All			Female			Male		
	Mean HCC	Difference MCC - HCC	Difference LCC - HCC	Mean HCC	Difference MCC - HCC	Difference LCC - HCC	Mean HCC	Difference MCC - HCC	Difference LCC - HCC
Management mode, type of ground, landforms									
Individual management (YES)	0.3	0.0	-0.2***	0.7	0.1***	-0.2***	0.1	0.0***	-0.1***
		(-1.4)	(-23.3)		(6.9)	(-10.6)		(-4.4)	(-9.6)
Type of crop									
Food crop	0.7	-0.0*	-0.0***	0.5	-0.0**	0.0**	0.8	-0.0*	-0.1***
		(-1.6)	(-3.0)		(-2.0)	(2.1)		(-1.6)	(-8.7)
Cash crop	0.3	0.0	-0.1***	0.5	0.0***	-0.1***	0.2	0.0	0.0
		(0.9)	(-7.1)		(2.0)	(-2.8)		(0.9)	(-0.9)
Vegetables	0.0	0.0*	0.1***	0.0	0.0	0.0**	0.0	0.0*	0.1***
		(1.8)	(16.3)		(0.1)	(2.4)		(1.6)	(15.2)
Type of land forms									
Plain	0.6	-0.1***	0.0*	0.6	0.0**	0.0	0.6	-0.1***	0.0
		(-9.4)	(-1.6)		(-2.5)	(-0.3)		(-9.3)	(-0.9)
Plateau	0.3	0.1***	0.0	0.3	0.1***	0.0	0.3	0.1***	0.0*
		(7.3)	(-0.7)		(3.0)	(0.2)		(6.5)	(-1.7)
Low-lands	0.1	0.0	0.0***	0.1	-0.0*	0.0	0.1	0.0**	0.0***
		(1.1)	(4.3)		(-1.8)	(1.0)		(2.2)	(4.8)
Slope	0.0	0.0***	-0.0	0.0	0.0**	-0.0**	-0.0**	0.0***	-0.0
		(4.8)	(-1.3)		(2.1)	(-2.5)		(4.3)	(-1.1)
Soil types									
Sandy soil	0.5	-0.1***	-0.1***	0.5	-0.0	-0.0*	0.5	-0.1***	-0.1***
		(-5.8)	(-7.8)		(-1.3)	(-1.9)		(-6.0)	(-8.1)
Clay soil	0.3	0.1***	0.0***	0.3	0.1***	0.0	0.3	0.1***	0.1***
		(8.6)	(6.1)		(3.8)	(1.1)		(7.9)	(6.9)
Lateriste soil	0.2	-0.0**	0.0*	0.2	-0.0***	0.0	0.2	0.0	0.0
		(-2.5)	(1.7)		(-3.0)	(0.7)		(-1.3)	(1.3)
Other soil	0.0	0.0	0.0**	0.0	0.0	0.0	0.0	0.0	0.0**
		(-1.1)	(2.3)		(-0.5)	(0.9)		(-0.9)	(2.3)
Inputs, use of storage technique									
Chemical fertilizers (YES)	0.2	0.0**	0.2***	0.1	-0.0	0.1***	0.2	0.0**	0.1***
		(2.3)	(18.8)		(-1.0)	(4.0)		(2.5)	(16.3)

Table D1 Characteristics of the plot by status of credit constraint

	Total			Female			Male		
Garbage as fertilizers (YES)	0.2	-0.1***	-0.1***	0.2	-0.1***	-0.1***	0.2	-0.0***	-0.1***
		(-7.2)	(-12.6)		(-5.4)	(-5.8)		(-5.3)	(-11.1)
Phytosanitary products (YES)	0.2	0.0***	0.3***	0.1	-0.0***	0.1***	0.2	0.0***	0.3***
		(3.3)	(30.8)		(-2.8)	(6.2)		(4.6)	(29.3)
Storage technique (YES)	0.3	0.0**	0.0**	0.3	0.0**	0.0	0.3	0.0**	0.0**
		(2.4)	(2.4)		(2.1)	(1.3)		(2.4)	(2.1)
Observations	8,786	12,403	13,584	6,600	9,409	10,846	2,186	2,994	2,738

t-stat in parentheses
* p<0.1 ** p<0.05 *** p<0.01
Source: EMC 2014, Agricultural household sample, authors calculations

Table D2: IV regression: Exogenous test of the IV regression of the credit constraint impact on consumption per capita

Test	Statistics
Underidentification test (Kleibergen-Paap rk LM statistic):	18,793
Chi-sq(3) P-val =	0,0003
Weak identification test (Cragg-Donald Wald F statistic):	33,732
(Kleibergen-Paap rk Wald F statistic):	14,054
Stock-Yogo weak ID test critical values: 5% maximal IV relative bias	13,91
10% maximal IV relative bias	9,08
20% maximal IV relative bias	6,46
30% maximal IV relative bias	5,39
10% maximal IV size	22,3
15% maximal IV size	12,83
20% maximal IV size	9,54
25% maximal IV size	7,8
Source: Stock-Yogo (2005). Reproduced by permission.	
NB: Critical values are for Cragg-Donald F statistic and i.i.d. errors.	
Hansen J statistic (overidentification test of all instruments):	3.344
Chi-sq(2) P-val =	0.1879
Instrumented: selectCci2	
Included instruments: logage sexeF nivedu2 nivedu3 proprietaire handicap dependacy nbadulteF logageCM typesol1 typesol2 typesol3 emplacementparcel modesecure1 modesecure2 modesecure3 2.zoneagroeco 3.zoneagroeco 4.zoneagroeco 5.zoneagroeco	
Excluded instruments: Wpropoassoprov mebreinstassoc assomenage	

Table D3: Result regressions of the credit constraints impact on consumption per capita (log scale): standard switching regression

Variables	Male sample				Female sample			
	Outcome equations			Selection equation	Outcome equations			Selection equation
	LCC	MCC	HCC	All	LCC	MCC	HCC	All
Farmer characteristics								
Age (log scale)	-0.16	-0.01	-0.30***	-0.32***	0.07	-0.01	-0.04	-0.04
	(0.16)	(0.07)	(0.06)	(0.12)	(0.12)	(0.05)	(0.04)	(0.12)
Education (ref = No education)								
Primary	0.14**	0.11**	0.10***	0.07	0.49**	0.07	0.26***	0.16
	(0.06)	(0.05)	(0.03)	(0.06)	(0.20)	(0.09)	(0.06)	(0.15)
Secondary or higher	0.23***	0.24**	0.16***	-0.02	0.06	0.25	0.22	-0.03
	(0.08)	(0.10)	(0.06)	(0.10)	(0.23)	(0.22)	(0.14)	(0.31)
Plot owner (Yes/No)	-0.05	-0.05	-0.02	0.02	-0.02	-0.02	0.12*	0.14
	(0.04)	(0.04)	(0.05)	(0.08)	(0.09)	(0.09)	(0.07)	(0.14)
Any Disability (Yes/No)	0.09	0.12	0.01	0.22**	-0.16	-0.09	-0.05	-0.21*
	(0.08)	(0.11)	(0.05)	(0.11)	(0.11)	(0.08)	(0.06)	(0.11)
Plot characteristics								
Ground types								
Sandy (Yes/No)	0.01	0.00	0.01	-0.04	0.01	-0.05**	0.03	-0.12***
	(0.01)	(0.01)	(0.01)	(0.04)	(0.03)	(0.03)	(0.02)	(0.04)
Clay (Yes/No)	-0.00	-0.01	-0.00	-0.10***	0.10	0.02	0.02	-0.19***
	(0.01)	(0.02)	(0.01)	(0.04)	(0.07)	(0.03)	(0.03)	(0.05)
Lateritic (Yes/No)	0.00	-0.00	-0.01	-0.06	0.02	-0.03	-0.01	-0.14**
	(0.02)	(0.02)	(0.01)	(0.04)	(0.04)	(0.04)	(0.02)	(0.05)
Is the plot within the village (Yes/No)	0.04	0.00	-0.08***	0.01	0.07	0.04	0.00	-0.05
	(0.03)	(0.04)	(0.03)	(0.06)	(0.07)	(0.05)	(0.04)	(0.09)
Type ground secure								
Official document (Yes/No)	-0.05*	0.03	0.03	-0.10	-0.05	-0.01	-0.07	-0.11
	(0.03)	(0.04)	(0.04)	(0.06)	(0.09)	(0.06)	(0.09)	(0.15)
Lease/loan (Yes/No)	-0.03**	0.00	-0.01	-0.03	-0.09***	-0.04	-0.05	-0.01
	(0.02)	(0.02)	(0.02)	(0.04)	(0.03)	(0.04)	(0.03)	(0.06)
Landowner (Yes/No)	-0.02*	0.00	-0.02	-0.01	-0.10***	0.00	-0.09***	0.00
	(0.01)	(0.01)	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.07)
Agroecological zones fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics								
Dependancy ratio	-0.06***	-0.05***	-0.07***	-0.04***	-0.06***	-0.04***	-0.07***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Number of female in the household	0.02	0.00	0.02*	0.07***	0.02	0.03	0.05***	0.05*
	(0.02)	(0.01)	(0.01)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)
hh head age (log scale)	0.01	-0.08**	0.19***	0.38***	-0.12*	0.03	0.00	0.10

Table D3 continued from previous page

	Male sample				Female sample			
	(0.09)	(0.04)	(0.04)	(0.06)	(0.07)	(0.05)	(0.03)	(0.07)
Identification variables								
hh members part of an association	—	—	—	-0.44	—	—	—	1.04*
(% of province population)				(0.45)				(0.58)
hh members part of an association	—	—	—	-0.20**	—	—	—	-0.17
decision-making body				(0.08)				(0.13)
hh members part of an association	—	—	—	-0.06***	—	—	—	-0.08***
				(0.01)				(0.03)
Constant	13.18***	13.15***	11.85***	—	13.35***	12.16***	12.20***	—
	(0.14)	(0.20)	(0.17)		(0.73)	(0.33)	(0.19)	
Parameters								
cutoff(1)	—	—	—	1.14***	—	—	—	-0.41
cutoff(2)	—	—	—	1.73***	—	—	—	0.42
ln σ_1	-0.88***	—	—	—	-0.78***	—	—	—
ln σ_2	—	-0.89***	—	—	—	-0.81***	—	—
ln σ_3	—	—	-0.65***	—	—	—	-0.78 ***	—
atanh ρ_{14}	0.11	—	—	—	0.40	—	—	—
atanh ρ_{24}	—	0.12	—	—	—	0.68***	—	—
atanh ρ_{34}	—	—	1.13***	—	—	—	0.88***	—
Observations	4,573				2,054			

t-stat in parentheses

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

Table D4: Result regressions of the credit constraints impact on consumption per capita (log scale): switching regression with sample selectivity correction

	Male sample					Female sample				
	Outcome equations			Selection equations		Outcome equations			Selection equations	
Variables	LCC	MCC	HCC	Probit	Ordered probit	LCC	MCC	HCC	Probit	Ordered probit
Farmer characteristics										
Age (log scale)	-0.14	0.01	-0.24***	-0.10	-0.30**	0.05	-0.02	-0.04	0.20*	-0.04
	(0.15)	(0.07)	(0.05)	(0.11)	(0.12)	(0.11)	(0.04)	(0.04)	(0.12)	(0.12)
Education (ref = No education)										
Primary	0.14**	0.11*	0.09***	-0.12**	0.07	0.50**	0.06	0.24***	0.17	0.15
	(0.06)	(0.06)	(0.03)	(0.05)	(0.06)	(0.20)	(0.08)	(0.06)	(0.11)	(0.15)
Secondary or higher	0.23***	0.24**	0.18***	-0.09	-0.03	0.08	0.25	0.23*	-0.08	-0.03
	(0.08)	(0.10)	(0.06)	(0.08)	(0.10)	(0.23)	(0.22)	(0.14)	(0.16)	(0.31)
Plot owner (Yes/No)	-0.05	-0.05	-0.02	0.06	0.01	-0.01	-0.02	0.11*	-0.01	0.14
	(0.04)	(0.04)	(0.04)	(0.08)	(0.07)	(0.06)	(0.08)	(0.06)	(0.15)	(0.14)
Any Disability (Yes/No)	0.08	0.11	-0.05	0.03	0.22*	-0.20**	-0.08	-0.05	0.27**	-0.20*
	(0.08)	(0.11)	(0.04)	(0.09)	(0.12)	(0.08)	(0.08)	(0.06)	(0.13)	(0.11)
Plot characteristics										
Ground types										
Sandy (Yes/No)	0.01	0.01	0.02	0.01	-0.04	-0.00	-0.05*	0.04*	_	-0.12***
	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)	(0.02)	(0.03)	(0.02)		(0.04)
Clay (Yes/No)	0.00	-0.01	0.03**	-0.01	-0.10***	0.08***	0.03	0.03	_	-0.20***
	(0.01)	(0.02)	(0.01)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)		(0.05)
Lateritic (Yes/No)	0.00	0.00	0.01	0.00	-0.05	0.01	-0.03	-0.01	_	-0.14**
	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.02)	(0.04)	(0.02)		(0.05)
Is the plot within the village (Yes/No)	0.04	0.00	-0.08***	-0.06	0.02	0.05	0.03	0.00	_	-0.06
	(0.03)	(0.04)	(0.03)	(0.06)	(0.06)	(0.05)	(0.05)	(0.04)	_	(0.09)
Type ground secure										
Official document (Yes/No)	-0.04	0.03	0.06	0.01	-0.11*	-0.06	-0.02	-0.06	_	-0.10
	(0.03)	(0.03)	(0.04)	(0.05)	(0.06)	(0.08)	(0.06)	(0.09)		(0.15)
Lease/loan (Yes/No)	-0.03**	0.01	-0.00	0.01	-0.03	-0.09***	-0.04	-0.05*	_	-0.01
	(0.02)	(0.02)	(0.01)	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)		(0.06)
Landowner (Yes/No)	-0.02*	0.00	-0.02	0.02	-0.01	-0.10***	0.00	-0.09***	_	0.01
	(0.01)	(0.01)	(0.01)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	_	(0.07)
Agroecological zones fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics										
Dependancy ratio	-0.06***	-0.05***	-0.06***	-0.00	-0.04***	-0.07***	-0.04***	-0.06***	-0.01	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Number of female in the household	0.02	0.00	0.01	-0.04***	0.08***	0.03	0.03	0.05***	-0.03	0.05*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.04)	(0.02)	(0.01)	(0.03)	(0.03)
hh head age (log scale)	-0.00	-0.09**	0.10***	0.05	0.37***	-0.11*	0.04	-0.00	-0.02	0.10

Table D4 continued from previous page

	Male sample					Female sample				
	(0.08)	(0.04)	(0.03)	(0.06)	(0.07)	(0.06)	(0.05)	(0.03)	(0.06)	(0.07)
Identification variables										
hh members part of an association	—	—	—	—	-0.75	—	—	—	-3.13***	0.85
(% of province population)					(0.56)				(1.04)	(0.53)
hh members part of an association	—	—	—	—	-0.24***	—	—	—	—	-0.15
decision-making body					(0.09)					(0.12)
hh members part of an association	—	—	—	—	-0.05***	—	—	—	-0.03	-0.08***
					(0.02)				(0.03)	(0.03)
Is any hh member part of	—	—	—	—	—	—	—	—	0.10	—
an association (Yes/No)									(0.08)	
Constant	13.18***	13.21***	12.68***	0.57**	—	13.61***	12.19***	12.31***	0.46	—
	(0.14)	(0.19)	(0.16)	(0.25)		(0.48)	(0.34)	(0.19)	(0.38)	
Parameters										
cutoff(1)	—	—	—	—	1.17***	—	—	—	—	-0.39
cutoff(2)	—	—	—	—	1.76***	—	—	—	—	0.44
ln σ_1	-0.89***	—	—	—	—	-0.71***	—	—	—	—
ln σ_2	—	-0.91***	—	—	—	—	-0.84***	—	—	—
ln σ_3	—	—	-0.89***	—	—		—	-0.83***	—	—
atanh ρ_{14}/ρ_{15}	0.01	—	—	—	—	-0.17	—	—	—	
	0.02	—	—	—	—	0.62	—	—	—	—
atanh ρ_{24}/ρ_{25}	—	0.01	—	—	—	—	-0.17	—	—	
	—	0.02	—	—	—	—	0.62	—	—	—
atanh ρ_{34}/ρ_{35}	—	—	0.01	—	—	—		-0.17	—	—
	—	—	0.02	—	—	—	—	0.62	—	—
atanh ρ_{45}	—	—	—	0.00	—	—	—	—	— 0.00	—
Observations	6,488					3,244				

t-stat in parentheses

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

Table D5: Result regressions of the credit constraints impact on plot standardized yields (log scale): standard switching regression

	Male sample				Female sample			
	Outcome equations			Selection equation	Outcome equations			Selection equation
Variables	LCC	MCC	HCC	All	LCC	MCC	HCC	All
Farmer characteristics								
Age (log scale)	0.17*	-0.10	-0.04	0.39***	0.19	0.23	-0.15	0.10
	(0.10)	(0.11)	(0.07)	(0.07)	(0.24)	(0.17)	(0.12)	(0.12)
Education (ref = No education)								
Primary	-0.21	-0.08	-0.37	0.92***	0.49**	0.07	0.26***	0.16
	(0.28)	(0.61)	(0.43)	(0.32)	(0.20)	(0.09)	(0.06)	(0.15)
Secondary or higher	0.04	-0.32	-0.44	0.92***	0.06	0.25	0.22	-0.03
	(0.32)	(0.62)	(0.44)	(0.33)	(0.23)	(0.22)	(0.14)	(0.31)
Plot owner (Yes/No)	0.09	0.10	-0.13*	0.01	-0.02	-0.02	0.12*	0.14
	(0.10)	(0.12)	(0.07)	(0.07)	(0.09)	(0.09)	(0.07)	(0.14)
Any Disability (Yes/No)	-0.03	0.31	0.03	0.15	-0.16	-0.09	-0.05	-0.21*
	(0.12)	(0.22)	(0.11)	(0.10)	(0.11)	(0.08)	(0.06)	(0.11)
Plot characteristics								
Ground types								
Sandy (Yes/No)	0.14**	-0.10	-0.23***	0.00	0.01	-0.05**	0.03	-0.12***
	(0.06)	(0.10)	(0.06)	(0.05)	(0.03)	(0.03)	(0.02)	(0.04)
Clay (Yes/No)	0.20***	-0.16	-0.07	-0.12**	0.10	0.02	0.02	-0.19***
	(0.07)	(0.10)	(0.06)	(0.05)	(0.07)	(0.03)	(0.03)	(0.05)
Lateritic (Yes/No)	—	—	—	—	0.02	-0.03	-0.01	-0.14**
					(0.04)	(0.04)	(0.02)	(0.05)
Is the plot within the village (Yes/No)	0.05	0.16**	0.18***	0.06	0.07	0.04	0.00	-0.05
	(0.05)	(0.07)	(0.05)	(0.04)	(0.07)	(0.05)	(0.04)	(0.09)
Type ground secure								
Official document (Yes/No)	-0.30*	-0.10	-0.08	-0.22	-0.05	-0.01	-0.07	-0.11
	(0.17)	(0.21)	(0.14)	(0.15)	(0.09)	(0.06)	(0.09)	(0.15)
Lease/loan (Yes/No)	-0.04	0.05	-0.04	-0.05	-0.09***	-0.04	-0.05	-0.01
	(0.11)	(0.15)	(0.08)	(0.07)	(0.03)	(0.04)	(0.03)	(0.06)
Landowner (Yes/No)	-0.08	0.10	0.11**	-0.03	-0.10***	0.00	-0.09***	0.00
	(0.09)	(0.10)	(0.05)	(0.06)	(0.03)	(0.03)	(0.03)	(0.07)
Agroecological zones fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household characteristics								
Dependancy ratio	-0.04***	-0.00	-0.01	-0.04***	-0.06***	-0.04***	-0.07***	-0.04***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Number of female in the household	0.05**	0.01	0.02	0.06***	0.02	0.03	0.05***	0.05*
	(0.03)	(0.03)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)
hh head age (log scale)	—	—	—	—	—	—	—	—

Table D5 continued from previous page

	Male sample				Female sample			
Other characteristics								
Unproductive expenses	-0.04***	-0.00	-0.01	-0.04***	-0.06***	-0.04***	-0.07***	-0.04***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
Relief of the plot (Ref = Lowland)								
Continental shelf	—	—	—	—	0.03	0.07	0.02	0.03
					(0.16)	(0.16)	(0.10)	(0.10)
Shallows	—	—	—	—	-0.23	0.60**	0.22	0.06
					(0.17)	(0.25)	(0.17)	(0.13)
Slope	—	—	—	—	-0.04	-0.10	-0.15	-0.03
					(0.30)	(0.21)	(0.20)	(0.17)
Identification variables								
hh members part of an association	—	—	—	—	—	—	—	0.48
(% of province population)								(0.44)
hh members part of	—	—	—	-0.24***	—	—	—	-0.13
an association decision-making body				(0.06)				(0.19)
Within hh proportion of	—	—	—	-0.23***	—	—	—	-0.39***
members part of an association				(0.06)				(0.11)
Constant	0.71	1.33*	1.02*		0.21	-0.26	0.87	
	(0.48)	(0.75)	(0.53)		(0.91)	(0.67)	(0.57)	
Parameters								
cutoff(1)	—	—	—	1.42***	—	—	—	-0.22
cutoff(2)	—	—	—	2.00***	—	—	—	0.35
ln σ_1	0.33***	—	—	—	0.18***	—	—	—
ln σ_2	—	0.34***	—	—	—	0.28***	—	—
ln σ_3	—	—	0.26***	—	—	—	0.31 ***	—
atanh ρ_{14}	0.66***	—	—	—	0.66***	—	—	—
atanh ρ_{24}	—	0.66***	—	—	—	0.66***	—	—
atanh ρ_{34}	—	—	0.66***	—	—	—	0.66***	—
Observations	4,573				2,054			

t-stat in parentheses

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

Table D6: Treatment effects of credit constraints on the consumption per capita (log scale) by farmer gender: standard switching regression

Sample	**Categories**	**Obs.**	**Treated/ Untreated (1)**	**Counterfactual (2)**	**Diff. (1) - (2)**	**t-stat**
Panel A: Average Treatment on the Treated (ATET)						
Men	Low (Treated) VS Medium (Counterfactual)	1321	12.17 (0.47)	12.12 (0.17)	0.05***	4.43
	Low (Treated) VS High (Counterfactual)	1321	12.17 (0.47)	12.08 (0.23)	0.09***	7.88
Women	Low (Treated) VS Medium (Counterfactual)	257	12.18 (0.51)	12.04 (0.15)	0.15***	5.03
	Low (Treated) VS High (Counterfactual)	257	12.18 (0.51)	12.09 (0.22)	0.09***	3.28
Panel B: Average Treatment on the Untreated (ATU)						
Men	Low (Counterfactual) VS Medium (Untreated)	944	12.17 (0.25)	12.11 (0.46)	0.07***	5.01
	Low (Counterfactual) VS High (Untreated	2308	12.21 (0.23)	12.04 (0.47)	0.17***	18.79
Women	Low (Counterfactual) VS Medium (Untreated)	491	12.20 (0.34)	11.98 (0.40)	0.21***	11.16
	Low (Counterfactual) VS High (Untreated)	1306	12.51 (0.29)	12.04 (0.46)	0.47***	40.63

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$