# The role of social protection in mitigating the effects of weather shocks. A stochastic frontier analysis

Francisco Pereira Fontes, Silvio Daidone[1]

[1]Food and Agriculture Organization of the United Nations, Rome, Italy. Email: francisco.pereirafontes@fao.org silvio.daidone@fao.org

December 7, 2020

**Abstract**

We study how participation into various social assistance programs like public works, cash and in-kind transfers can mitigate the negative relationship between adverse weather shocks and agricultural production, thus acting as a tool of climate change adaptation. We use panel data from Ethiopia and adopt a stochastic frontier approach, analyzing the influence of these programs on farmer's efficiency and how these effects on agricultural production are shaped jointly with adverse weather shocks. We find heterogeneous effects of social protection, with public works negatively associated with productive efficiency, while cash transfers are more neutral to production and positively associated with farming profitability. These effects are magnified as a consequence of adverse weather shocks.

**Keywords:** Cash transfers; in-kind transfers; public works; stochastic frontier; weather shocks; agricultural production; Ethiopia

# 1 Introduction

In the past three decades, the number of weather anomalies, including extreme heat, droughts, floods and storms, has doubled, with an average of 213 of these events occurring every year during the period of 1990–2016 (FAO et al. 2018). These extreme climate events lead to an increase of disasters, which have severe impacts on people's lives and livelihoods (Hallegatte et al. 2016). Rural households in developing countries are particularly vulnerable to weather shocks for several reasons. First, they depend on weather-sensitive income generating activities such as agriculture. Bad weather can increase the unitary cost of production, widening the distance between observed production and the feasible production frontier. Second, poor rural households are more likely to live in high-risk geographical locations because they tend to be the most affordable, and have limited capacity to cope with climate hazards due to lack of saving, weaker social networks and low asset base (del Ninno and Lundberg 2005; Jacobsen 2012; Lohmann and Lechtenfeld 2015; Shehu and Sidique 2015). Third, developing countries have weaker institutional arrangements and early warning/early action systems for weather events, very often limited by severe financial constraints (Kellet and Caravani 2013; Hallegatte et al. 2017).

By exploiting exogenous variation in weather outcomes over time, a thriving literature seeks to examine and causatively identify how climatic factors influence economically relevant outcomes (Dell, Jones, and Olken 2014). Unsurprisingly, because of the natural relationship between weather and agricultural production, agriculture has been the center of the existing research on the impacts of climate. One stream of research looks at the impacts of climate at a regional/national scale, using aggregate economic data (Deschênes and Greenstone 2007; Hsiang 2010; Dell, Jones, and Olken 2012). A second body of research analyzes the relationship between climatic factors and individual commodity production or productivity, such as crop or milk yields (Mukherjee, Bravo-Ureta, and De Vries 2012; Key and Sneeringer 2014; Burke and Emerick 2016). Finally, a third stream of research analyzes farm-level adaptation to climate change, such as irrigation investments, crop switching and migration, finding generally little to no efficacy in reducing agricultural climate losses (Hornbeck 2012; Burke and Emerick 2016; Taraz 2017, 2018) and significant information asymmetries and financial constraints preventing adaptation (Deressa et al. 2009; Di Falco, Veronesi, and Yesuf 2011).

The limited efficacy of private adaptation suggests a potentially significant role for public policies promoting large-scale adaptation to climate change. Social protection programs can complement both formal risk management tools provided by markets and informal support mechanisms from communities and informal insurance. While the importance of integrating weather risks within the planning of new and existing social protection programs has been already recognized by international organizations such as the World Bank and the Food and Agriculture Organization (Kuriakose et al. 2012; FAO and Red Cross Red Crescent Climate Centre 2019), very few national Government programs are explicitly tailored to protect households with low levels of adaptive capacity from weather-related shocks. One of the few considerable exceptions is represented by the Productive Safety Net Programme (PSNP) in Ethiopia, which was launched in 2005 by the Government and a consortium of donors as a joint response to chronic food insecurity in rural areas, going beyond the near-annual emergency appeals for food aid and other form of emergency assistance that characterized the previous decade.

During phase 1 and 2, spanning from 2005–2009 and 2009–2011, the PSNP provided cash or food to people with predictable food needs to enable them to improve their livelihoods and become more resilient to shocks in the future (van Domelen et al. 2010). In phase 3 (2011–2015), the PSNP expanded its coverage and improved the timeliness of cash transfers, increasing the shift from food to cash transfers. The fourth phase of PSNP (2015-2019), aimed at enhancing resilience to shocks and improving livelihoods, food security and nutrition for rural households vulnerable to chronic or recurrent food shocks. It reached about eight million beneficiaries nationwide and responded to the Social Protection Policy, validated in 2014, by including a series of new program elements, which aim to provide a transition towards a system of integrated service delivery in social protection and disaster risk management (Schubert 2015).

Most PSNP beneficiary households are engaged in public works (PW): criteria for selection are that a household is poor and food insecure, but also has able-bodied labor power. PW focus on integrated community-based watershed development, covering activities such as soil and water conservation measures and the development of community assets such as roads, water infrastructure, schools and clinics. The objective of these works is to contribute to livelihoods, disaster risk management and climate resilience, and nutrition. Households without labor capacity are recipients of cash transfers.

Our paper contributes generally to the thriving literature studying how social protection interventions affect livelihoods and agricultural production (Banerjee et al. 2015; Tirivayi, Knowles, and Davis 2016; Hidrobo et al. 2018; Daidone et al. 2019), and more specifically to the limited but growing body evidence published on the role played by social protection in helping individuals coping with weather shocks (de Janvry et al. 2006; Asfaw et al. 2017; Patnaik and Das 2017; Adhvaryu et al. 2018; Mueller et al. 2020). We study whether in Ethiopia the participation into the PSNP and the receipt of other in-kind social assistance programs can mitigate the negative relationship between adverse weather shocks and agricultural production, thus acting as a tool of climate change adaptation. First, we test whether being a PSNP beneficiary of public works or a PSNP cash transfer beneficiary or receiving other in-kind assistance (mostly free food) influences farmer's efficiency and how these effects on agricultural production are shaped jointly with adverse weather shocks. Second, we analyze whether the effects are heterogeneous across outcome variables, considering production, revenue and profit functions.

## 2 Conceptual framework

In this section we discuss how social assistance could affect farm incomes, revenues and profits and their sensitivity to weather shocks. There are several mechanisms through which various typologies of social assistance may influence these relationships, though the most important ones are probably the labor and the income channels. PWs bring about a labor reallocation by beneficiary household members with labor capacity from family farms to the temporary jobs provided by the program. This is expected to generate not only a reduction of overall farm income and sales, but also a reduction of productive efficiency if the work carried out under the PW scheme conflict with activities usually performed during the agricultural season. In the case of Ethiopia PSNP, this issue is particularly important, since the program targets food insecure subsistence farmers. The PW component of PSNP is expected to have an additional negative effect on productive efficiency in response to a covariate idiosyncratic shock too, because PSNP take-up will increase after the weather shock and this is likely to further reduce family labor on the farm for households with members engaged in PWs. With respect to farm profits, participation in a PW program has an ambiguous effect and depends on two factors: 1) whether households that cultivate land are net sellers or buyers of agricultural labor, and 2) the wage floor set by the Government for PW employment. If the PSNP wage is set above the market wage rate, this will lead to higher agricultural wages in the local rural economy (Imbert and Papp 2015; Muralidharan, Niehaus, and Sukhtankar 2020) and consequently to lower profit efficiency if households are net buyers of labor. If instead the wage floor is set below the equilibrium wage, this will depress wages in the private sector, and will increase profit efficiency if farmers are net buyers. The effects of adverse weather shocks on farm profits is ambiguous too, since equilibrium harvest-stage wage are always lower in bad than good weather for both households with and without PW beneficiaries (Rosenzweig and Udry 2014).

A labor reallocation from off-farm wage employment to family businesses on- or off-farm may occur also under a cash transfer. In fact, despite the classical prediction of a fall in working hours and earnings due to unexpected cash windfall, labor responses to cash transfer cannot be determined a priori, as they depend on multiple alternative mechanisms that can be broadly grouped as arising from missing markets, price effects from behavioral conditions attached to transfers, and dynamic and general equilibrium effects (Baird, McKenzie, and Özler 2018). Indeed Daidone et al. (2019) find that in the impact evaluation of seven cash transfers in sub-Saharan Africa, a reduction of wage labor in five countries is offset by an increase in family labor on- and off-farm only in Zambia only, where the program targeted households with labor capacity. Since the pure cash transfer component of the PSNP explicitly targets labor constrained households, we do not expect the labor channel to affect significantly farm production. However, cash transfers are expected to have some influence on farming through an income channel. Higher incomes can potentially increase crop yields and efficiency by relaxing households' liquidity constraints and allowing them to invest in modern inputs and assets. Further, they could contribute to a reduction of transaction costs and make households more engaged with markets (Prifti et al. 2020), hence increasing their revenues efficiency as well. Profit efficiency is also expected to be greater as a consequence of cash transfers if hired labor is perfectly substituted with household labor or if the cost of adopting more modern inputs is lower than the cost of hired labor. It is not clear however if higher incomes from cash transfers contribute to lower or greater sensitivity to adverse weather shocks. On the one hand, cash transfers may increase risk-taking behavior by their beneficiaries (Hennessy 1998; Moro and Sckokai 2013; Prifti et al. 2019), hence increase sensitivity to weather shocks. On the other hand, cash transfers may be invested in modern inputs that can reduce yields volatility, thus contributing to a decrease in the sensitivity to adverse weather.

In-kind transfers such as free food distribution can also have productive impacts. In particular, a food transfer may have an insurance function similar to the role of food crop production, thus alleviating the risk associated with the production of cash or higher-values crops or inducing greater off-farm economic opportunities (Margolies and Hoddinott 2014; Schwab 2019).[1] Further, as long as the in-kind transfer is infra-marginal (smaller than what was consumed prior to the intervention), there should be no difference in how labor supply responds to a cash or an in-kind transfer. However, an infra-marginal food transfer contributes to lowering the price variance of the overall food budget, thus reducing also the exposure to sudden price spikes of staple commodities, which may occur because of weather shocks.

1. Stated preferences of PSNP beneficiaries highlight the importance of the insurance function of in-kind transfers in rural Ethiopia: even though most PSNP payments were paid in cash, and even though the transaction costs associated with food payments were higher than payments received as cash, the majority of the beneficiary households stated that they prefer their payments only or partly in food, with higher food prices inducing shifts in stated preferences toward in-kind transfers, while more food-secure households and those closer to food markets and financial services are more likely to prefer cash (Hirvonen and Hoddinott 2020).

# 3 Data and methodology

## 3.1 Data

We use the three rounds of the Ethiopian Socioeconomic Survey (ESS) currently available(CSA 2012, 2014, 2016), covering three agricultural seasons (2011/12, 2013/14 and 2015/2016). The three rounds of data contain over 14 000 observations and more than 5000 households. However, since the value of agricultural production, sales and profits represent our outcomes of interest, we restrict the sample to households engaged in either crop production (including tree crops) or livestock herding. This leads to a final sample of 9309 observations.

Table 1 provides a description of the main variables used in the analysis, summarizing them by the status of participation in social protection programs. Column (1) shows the descriptive statistics for the full sample, while column (2) reports the group of households whose members do not have access to any social assistance program. Columns (3), (4) and (5) show the summary statistics for, respectively, those households participating in the PSNP Public Works component ('Public works', Column (3)), the PSNP cash transfer component ('Cash transfers', Column (4)), and recipients of free food ('Free food', Column (5)). Since the participation in these programs is not mutually exclusive, we include the summary statistics for those households participating in more than one social protection program in a separate column (Column (6)).

TABLE 1 HERE

Table 1 highlights that groups differ in several ways in terms of their characteristics. First, the total value of farm production is higher for those households not participating in social protection programs. These mean differences are statistically significant and large, with the exception of the difference between the group of households benefiting from PWs and those without social assistance. However, despite having a lower value of production, households with access to social protection programs, with the exception of those receiving free food, have higher monetary profits. These are defined as the difference between the revenues from sales and the monetary costs of production.[2] Part of this seems to be explained by the fact that sales are, on average, higher for households participating in social protection programs (with the exception of those receiving free food). Beyond the higher value of sales, however, households not benefiting from social protection programs also have higher production costs, purchase higher levels of inputs (especially fertilizer) and use more labor (including hired labor). This is not surprising given the average size of land owned is approximately 35% larger than that of households benefiting from social protection programs.

Weather anomalies were estimated using satellite-derived Normalized Difference Vegetation Index (NDVI) imagery over the study areas, and are defined as the woreda specific deviation of the current NDVI from the long-term mean, divided by its long-run standard deviations.[3] Formally, the NDVI anomaly $NA$ in woreda $w$ in year $t$ is given by:

$$NA_{wt} = \frac{NDVI_{wt} - \mu^{LR}(NDVI_w)}{\sigma^{LR}(NDVI_w)} \quad (1)$$

2. The definition used includes all costs of purchased inputs (labor, seeds, land rental, etc.) as well as any other expenses related to farm production. The opportunity cost of household labor is not included in this definition.

3. NDVI data have been retrieved from the Earth Observatory of NASA, available at https://www.earthobservatory.nasa.gov/features/MeasuringVegetation.

$\mu^{LR}$ and $\sigma^{LR}$ are woreda mean and standard deviation of the NDVI over the long run from 2000 to the survey year. These anomalies measure the magnitude of the weather shock relative to the long-term mean of the NDVI. In an agricultural context, NDVI has been shown to be related to crop productivity (Johnson 2014). In other words, as expected, higher values of the NDVI (which denote better weather conditions) are associated with higher crop yields. As shown in figure S1, woredas in Afar and Somali region have the lowest values of the long-run mean of the NDVI, which is likely to denote lower overall agricultural potential. In terms of their exposure to weather conditions, table 1 also shows that households benefiting from social protection programs, on average, live in areas with both lower agricultural potential and have been more exposed to weather shocks. The former is proxied by the lower value of the long-term average of the NDVI, whereas weather shocks are proxied by the deviations from the long-term NDVI, which are consistently lower for households benefiting from social protection programs. This is not unexpected since, in general, households targeted by social protection programs tend to be more vulnerable and often live in areas more exposed to extreme weather events.

We also note that households benefiting from social protection programs tend to own fewer agricultural assets, represented by an index constructed with principal component analysis, and are more likely to be headed by a female. This is particularly striking in the case of those benefiting from free food, where this is the case for almost half of the households. Finally, households with no access to social protection programs are more distant to large cities than households in the PWs group and those receiving free food, but they are are closer to large cities than cash transfer beneficiaries. This points out probably to the difficulty of logistics for free food delivery and PWs, while cash transfers are relatively easier to organize also in most remote rural areas.

### 3.2 Stochastic Frontier Model

We adopt a Stochastic Frontier framework to estimate farmer's technical efficiency and its determinants (Aigner, Lovell, and Schmidt 1977; Meeusen and van den Broeck 1977; Kumbhakar and Lovell 2000). Using the original model proposed by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977), the single output stochastic frontier production function is defined as:

$$y_i = f(x_i, \beta) exp(v_i - u_i) \tag{2}$$

Where $y_i$ is the dependent variable of interest for farmer i (in our case farm income, sales and profits), $x_i$ is a vector of inputs for farmer i. These could include factors of production such as land, labor and different inputs used in the production process (e.g. fertilizers). $\beta$ represents the vector of technology parameters associated to the inputs of production. $v_i$ is an independently and identically distributed (iid) random error distributed as a N(0,$\sigma^2$ ). This term represents random factors that, not under the control of a farmer. Finally, the term $u_i$ is represents the inefficiency term and captures those factors that prevent farmer i from being efficient.

Following equation 2, and given that the frontier of farmer i is given by the expression $y_i^* = f(x_i, \beta) exp(v_i)$, the measure of technical efficiency for a given observation can be defined as:

$$TE_i = \frac{y_i}{y_i^*} = \frac{f(x_i, \beta)exp(v_i - u_i)}{f(x_i, \beta)exp(v_i)} = exp(u_i) \tag{3}$$

Given the relationship described in equation 3, a given household can be described as efficient when the technical efficiency score is equal to 1. Any value below 1 indicates the presence of inefficiency, as a household is not producing the maximum achievable output. Values further away from 1 indicate higher levels of inefficiency. Assuming the simplest a Cobb-Douglas functional form[4] for the deterministic part of the frontier, we can re-write equation 2 as follows:

$$ln(y_{it}) = \beta_0 + \sum_{j}^{J} \beta_j ln(x_{jt}) + v_{it} + u_{it} \tag{4}$$

An important aspect in the stochastic frontier analysis literature relates to the variables that influence the inefficiency term $u_i$. The most common approaches to including these variables in the inefficiency term are those suggested by Kumbhakar, Ghosh, and McGuckin (1994) and Huang and Liu (1994). The authors essentially propose to parameterize the mean of the pre-truncated inefficiency distribution, which can be expressed as follows:

$$u_{it} = \delta_0 + \sum_{k}^{K} \delta_k * Z_{kit} + \eta \tag{5}$$

One challenge that is particularly prevalent in agricultural economics when estimating equation 4 is the existence of zero and negative values for several key variables. Many farmers do not use fertilizer and monetary profits may well be negative for some farmers and therefore if we were to use the log transformation of these farmers, we would be forced to drop a large number of observations. We opt to follow the approach proposed in Bellemare and Wichman (2020) and use a different transformation, namely the hyperbolic sine transformation (IHS). This approach has two key advantages over alternative treatments of zero and negative values. First, it does not introduce a bias in the estimated coefficients, which occurs when a small number is added to 0, as first suggested by MaCurdy and Pencavel (1986). Second, it is able to handle negative values, which are not handled in the correction proposed by Battese (1997)[5]. As such, throughout the paper, rather than estimating equation 4, we estimate the following benchmark equation:

$$\text{arcsinh}(y_i) = \beta_0 + \sum_{j}^{J} \beta_j * \text{arcsinh}(x_{jt}) + \sum_{t}^{T} \beta_t d_t + \sum_{r}^{R} \beta_r * d_r + v_i - u_i \tag{6}$$

4. We use a Cobb-Douglas specification as the main functional specification, but test the robustness of the results to alternative (i.e. translog) specifications.

5. This correction essentially consists in creating an intercept (by creating a dummy variable for the use of an input) and then adding 1 to the value before taking the log. In principle, this gives unbiased coefficients, but does not handle negative values, which is important in our case.

Where the term arcsinh stands for the hyperbolic sine transformation. The full list of variables used to estimate the frontier and the inefficiency are available in Table S1 in the Supplementary Material file. With regards to the estimation of the frontier, in addition to the inputs to production, we also include year- and region-specific dummy variables to capture year-specific shocks that are common to the full sample as well as region-specific shifts to the frontier, which capture factors such as region-specific policies and/or production constraints.

Finally, as mentioned in Kumbhakar and Lovell (2000) the presence of unobservable heterogeneity in $u_i$ and $v_i$ may affect the inference in SF models. As such, as a robustness check to the canonical stochastic frontier model, we also estimate equation 6 using the Pairwise Difference Estimator (PDE), which allows the incorporation of time-invariant unobservable heterogeneity in the SFM model, while avoiding the incidental parameter bias of the Greene 'True Fixed Effects' model (Belotti and Ilardi 2018; Greene 2005a, 2005b). All the results presented below were estimated using the commands *sfpanel* and *sftfe* (Belotti et al. 2013; Belotti and Ilardi 2014; Belotti et al. 2015).

# 4 Results and Discussion

## 4.1 Farm production value

Table 2 shows the estimated coefficients for the variables included in the term using the value of farm production as a dependent variable. Since our aim is to analyze the relationship between social protection, weather shocks and inefficiency, we only include the inefficiency equation and omit the deterministic part of the frontier, which is included in the supplementary material (Table S2).

As can be seen in table 2, most variables display the expected sign[6]. Households with more agricultural assets, with larger shares of irrigated areas and those with more household members have higher levels of efficiency. The opposite holds true for those households that have a female-head and that are farther away from a city (proxy for market access). Perhaps surprisingly, households with higher levels of education are more inefficient. This is likely because more educated households have more off-farm opportunities, which acts as a disincentive to work on farm.

Turning to the main variables in our analysis, positive deviations in the NDVI, which proxy better weather, lead to higher levels of efficiency. This is both intuitive and consistent with findings in the broader stochastic frontier literature, which tend to find that increased heat stress and worsening climatic conditions tend to lead to higher inefficiencies (Key and Sneeringer 2014; Wang et al. 2017).

6. A negative coefficient means that the variable is associated with a lower level of inefficiency (i.e. more efficient).

With regards to social protection programs, we consistently find a positive effect of participation in PW programs on inefficiency. This means that households that participate in PW programs have lower farm income relative to their potential. A potential explanation for this result is that PW programs are likely to act as a disincentive to produce on-farm, since they divert part of the household labor off-farm, thereby decreasing farm production. However, more interestingly, the interaction with our weather shock variable (in columns (2), (4), (6) and (8)) displays a negative sign and is significant throughout. Together with the positive coefficient on participation in PW programs, this means that participation in public works programmes leads to higher inefficiencies when weather conditions are worse.[7] We argue that the mechanism explaining this relationship are likely to be similar to the ones found by Branco and Feres (2020) in the case of Brazil, who find that, owing to the lower returns to agriculture during droughts, households increasingly attempt to find off-farm opportunities and reduce their amount of on-farm work. In this case, PW programs are likely to amplify this effect as they create the jobs that allow people to move off-farm, leading to lower farm income. As shown in Table 2, this result is robust to different functional specifications and choice of estimators and, as we show in Table S5, it is also robust to the use of alternative weather variables.[8]

With regards to the other social protection programs, broadly speaking, the results are not significant, although we note that cash transfers seem to be associated with lower inefficiencies whereas the opposite holds true for free food.

TABLE 2 HERE

## 4.2 Farm sales

Table 3, below, shows the estimates for the inefficiency equation when using sales as a dependent variable (the full table is available in the supplementary material, see Table S3). The coefficients on the exogenous determinants of inefficiency other than social protection remain very similar to the results discussed in Table 2 for farm income. However, the sign of the coefficients on the social protection variables are very different compared to the previous outcome indicator and point to heterogeneous effects of these programs. Similar to the case of farm income, PW programs lead to lower levels of efficiency, probably through a disincentive to work on-farm which translate also in lower market engagement. This result is significant in six out of the eight specifications with no interaction terms. The interaction with the NDVI anomalies, as in the case of the farm income results, is consistently negative, although this is only significant in three of eight regressions where the interaction is included.

7. A worsening of the weather conditions is a reduction in the NDVI, hence the effect on inefficiency becomes positive.

8. As a measure of sensitivity of the NDVI, we use rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), available at https://www.chc.ucsb.edu/data/chirps. Rainfall anomalies with CHIRPS were standardized in a similar way to the NDVI, by subtracting the long-run mean and dividing by the standard deviation of the indicator, both calculated at woreda level.

In contrast to participation in PW, households receiving food aid is associated with higher levels of efficiency. This implies that households that receive food aid sell amounts closer to their sales potential. We explain the result by the fact that, despite having no effect on farm production (insignificant effect in Table 2), the fact that the household receives free food reduces the need for self-consumption. In turn, this allows households to sell larger quantities of their produce. This result is statistically significant in eight of the sixteen regressions, but is not robust to fixed effects specification. Looking at the interaction term with the NDVI, we note that it tends to be negative. This is plausible since, in years where the weather is particularly bad, own production is lower and therefore, despite receiving free food, the household may not have produced enough to cover its subsistence needs. This may prompt the household to use this additional food for consumption rather than selling to the market. However, while the sign of the coefficient can be explained, it remains insignificant in the eight specifications where it is estimated.

TABLE 3 HERE

### 4.3 Farm monetary profits

Table 4 shows the estimated coefficients for the inefficiency equation when using monetary profits as the outcome variable (full table is available in the supplementary material, see 4. We find that all social protection programs are associated with an increase in efficiency (i.e. higher profits, relative to their potential), as shown by the negative coefficient associated to the three social protection programs, though their interaction with the weather anomalies variables are very heterogeneous.

Starting with the results of PW programs, we find that they lead to higher efficiency in terms of profits, while we previously found no effect on sales and a negative effect on production. These findings are consistent with the conceptual framework indicated previously and the available evidence concerning the PSNP implementation, which seems to indicate that PSNP wage rates for unskilled labor are generally lower than the market wage rate (Subbarao et al. 2013). Possibly, this is an indication of a substitution of household labor with hired labor on the family farm for PW beneficiary households.

Unlike the previous results on farm income and sales, we find that cash transfers also have a positive effect on profit efficiency and that this effect is greater in the presence of adverse weather shocks. There are two potential explanations for this pattern. One explanation for this is that households that receive cash transfers are able to invest in modern productive inputs, which makes the activity more profitable in the presence of weather shocks. A second potential explanation is that the effects operate through the reduction in hired labour. Specifically, cash transfers have been found to increase the time a household spends working on farm (Boone et al. 2013; Prifti et al. 2017) and this effect may be larger in years characterized by negative weather shocks. As such, this could lead to a shift away from hired labour to household labour, which would lower costs. The fact that households that participate in cash transfers have the lowest costs in terms of hired labour would seems to lend some support to this hypothesis.

Finally, the result of profit efficiency on free food beneficiaries are consistent with previous findings. The dummy variable displays a negative and significant coefficient for all specifications and the interaction with the NDVI is also negative, though insignificant for the fixed effects specifications. In other words, households receiving free food are more profit-efficient, but that, in the presence of negative weather shocks, this effect is lower. We argue that this is because in good years, the additional food, together with own production, may satisfy the needs of the household who may even be able to sell some of its own output. However, in years of bad weather, the lower own production levels due to the weather shock may prompt households to use the free food for own consumption, rather than sales. This would explain why the effect on efficiency is higher when there are positive (or in the absence of) weather shocks.

TABLE 4

As a robustness check we carried out the same set of estimates with an alternative, rainfall-based, weather variable and report the results in table S7. Overall, most of the results remain similar in terms of sign and significance. However, the interaction between the weather shock and the cash transfer dummy variable loses statistical significance.

## 5 Conclusions and discussion

Higher temperatures and unpredictable rainfall patterns caused by climate change are expected to have adverse effects on crop yields during the coming decades. The agricultural sector in many African countries is particularly vulnerable to these weather shocks, as it remains largely based on rain-fed agriculture and characterized by low adaptive capacities of farmers to adopt management practices that reduce the exposure to such shocks. In Ethiopia, despite the robust growth of the services and industry sectors in the last decade, agriculture still employs around two thirds of the labor force, accounts for about one third of the gross domestic product and is heavily dependent on rainfalls. Climate change has therefore the potential to trigger food shortages, exacerbating food insecurity in many areas of the country. To address this, the Government of Ethiopia has moved away from *ad hoc* responses to a planned systematic approach, embodied originally in the Food Security Programme launched in 2005 and more recently in the National Social Protection Policy of 2014. Social protection is now at the center of Ethiopia's development policy, with spending equivalent to 2.77% of gross domestic product on average between 2012 and 2016 (Endale, Pick, and Woldehanna 2019). Although domestic financing has increased considerably in recent years, donors financed approximately 60% of social protection spending (*ibidem*).

Given the structure of the Ethiopian economy and the high exposure to weather shocks, it is essential to understand how the large investment made by the Government in social protection programs can contribute to increased resilience of chronically and transitorily food-insecure households. Several impact evaluations of the Productive Safety Nets Programme were conducted since the program started, highlighting its positive impacts on food security and household well-being (Gilligan, Hoddinott, and Taffesse 2009; Behrane et al. 2014; Hoddinott and Mekasha 2020). Studies of the PSNP impacts on production and productivity are scarce and point to a positive effect of the PSNP only when combined with other livelihood interventions, but not when provided alone (Hoddinott et al. 2012).

In this paper, we seek to understand the potential contribution of different social protection programs on poor farmers' agricultural production in rural Ethiopia, and their interaction with weather anomalies. We find highly heterogeneous effects, where participation into a cash-for-work scheme crowds-out work on the family farm and reducing productive efficiency, especially for farmers exposed to bad weather. We also find evidence that unconditional cash transfers to households without labor capacity do not have any significant effect on farm income and sales, independently of the weather realizations, but improves the family farm profitability, especially in the face of an adverse weather shock. Finally, food transfers do not lead to changes in farm production, but lead to higher sales, which translate into higher profits farmers when farmers are exposed to positive weather shocks. The results are consistent with the labor and income channels hypothesized in the conceptual framework.

The sensitivity of farm production due to the PSNP is very relevant for the policymakers. Under climate change, farmers will be increasingly vulnerable to weather anomalies and therefore it is crucial to formulate social protection programs that are able to mitigate weather risk. The original objective of the PSNP was to provide transfers to chronically insecure households to smooth consumption and avoid distress sale of assets in times of crises. Households with labor capacity were engaged in labour-intensive projects designed to build community assets and happening between the months of January and June, so as not to interfere with farming activities which, in most regions, occur in the second half of the year (Gilligan, Hoddinott, and Taffesse 2009). However, according to our estimates, it seems that this objective has only partially been met and suggests some programmatic implications for the PSNP that have been already highlighted by previous impact evaluation studies: 1) making sure PW activities do not overlap with key phases of the agricultural cycle; 2) PSNP wage payments are disbursed timely to allow investment in agricultural inputs and assets. Further, the reduced productive efficiency of PWs during adverse weather shocks is clearly concerning from a food security perspective. It entails that either the public infrastructures created and/or rehabilitated under the PSNP do not contribute to total factor productivity growth or that farmers do not have easy access to modern inputs that can reduce yields volatility. Our findings therefore suggest actions on these directions. Finally, while setting a low daily wage rate for PW activities under the PSNP has been crucial for targeting and avoiding significant inclusion errors, it may have had as unintended consequence the depression of local wages, thus penalizing households that are net sellers of casual agricultural labor, who might now bear a greater share of the cost associated with weather shocks.

The fact that we found no result cash transfers on productive efficiency is not surprising. The limited amount of the transfers does not seem to have induced significantly liquidity-constrained households to make investments in more modern and risk-reducing inputs or technologies. This could be related to their remoteness and distance to markets. Therefore, to maximize the impacts of these unconditional transfers, beyond increasing the size of the grants, policymakers might consider providing complementary productive interventions, as well as promoting risk-management before future shocks occur.

## References

Adhvaryu, A., A. Nyshadham, T. Molina, and J. Tamayo. 2018. *Helping Children Catch Up: Early Life Shocks and the PROGRESA Experiment.* NBER Working Paper Series 24848. Cambridge, MA: National Bureau of Economic Research.

Aigner, D., C. Lovell, and P. Schmidt. 1977. "Formulation and estimation of stochastic frontier production function models." *Journal of econometrics* 6 (1): 21–37.

Asfaw, S., A. Carraro, B. Davis, S. Handa, and D. Seidenfeld. 2017. "Cash transfer programmes, weather shocks and household welfare: evidence from a randomised experiment in Zambia." *Journal of Development Effectiveness* 9 (4): 419–442.

Baird, S., D. McKenzie, and B. Özler. 2018. "The effects of cash transfers on adult labor market outcomes." *IZA Journal of Development and Migration* 8 (22).

Banerjee, A., E. Duflo, N. Goldberg, D. Karlan, R. Osei, W. Parienté, J. Shapiro, B. Thuysbaert, and C. Udry. 2015. "A multifaceted program causes lasting progress for the very poor: Evidence from six countries." *Science* 348 (6236).

Battese, G. 1997. "A note on the estimation of CobbDouglas production functions when some explanatory variables have zero values." *Journal of agricultural Economics* 48 (13): 250–252.

Behrane, G., D. Gilligan, J. Hoddinott, N. Kumar, and A. S. Taffesse. 2014. "A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values." *Economic Development and Cultural Change* 63 (1): 1–26.

Bellemare, M., and C. Wichman. 2020. "Elasticities and the Inverse Hyperbolic Sine Transformation." *Oxford Bulletin of Economics and Statistics* 82 (1): 50–61.

Belotti, F., S. Daidone, G. Ilardi, and V. Atella. 2013. "Stochastic frontier analysis using Stata." *The Stata Journal* 13 (4): 719–758.

———. 2015. "SFPANEL: Stata module for panel data stochastic frontier models estimation."

Belotti, F., and G. Ilardi. 2014. "sftfe: A Stata command for fixed-effects stochastic frontier models estimation." *Italian Stata Users' Group Meeting 2014 (No. 05). Stata Users Group.*

———. 2018. "Consistent inference in fixed-effects stochastic frontier models." *Journal of Econometrics* 202 (2): 161–177.

Boone, R., K. Covarrubias, B. Davis, and P. Winters. 2013. "Cash transfer programs and agricultural production: the case of Malawi." *Agricultural Economics* 44 (3): 365–378.

Branco, D., and J. Feres. 2020. "Weather Shocks and Labor Allocation: Evidence from Rural Brazil." *American Journal of Agricultural Economics.*

Burke, M., and K. Emerick. 2016. "Adaptation to climate change: Evidence from US agriculture." *American Economic Journal: Economic Policy* 8 (3): 106–140.

Central Statistical Agency of Ethiopia. 2012. "Rural Socioeconomic Survey 2011-2012 (ERSS)."

———. 2014. "Ethiopia Socioeconomic Survey 2013-2014."

———. 2016. "Ethiopia Socioeconomic Survey Wave 3 (ESS3) 2015-2016."

Daidone, S., B. Davis, S. Handa, and P. Winters. 2019. "The Household and Individual-Level Productive Impacts of Cash Transfer Programs in Sub-Saharan Africa." *American Journal of Agricultural Economics* 101 (5): 1401–1431.

de Janvry, A., F. Finan, E. Sadoulet, and R. Vakis. 2006. "Can Conditional Cash Transfer Programs Serve as Safety Nets in Keeping Children at School and from Working When Exposed to Shocks?" *Journal of Development Economics* 79:349–373.

del Ninno, C., and M. Lundberg. 2005. "Treading water: The long-term impact of the 1998 flood on nutrition in Bangladesh." *Economics and Human Biology* 3 (1): 67–96.

Dell, M., B. F. Jones, and B. A. Olken. 2012. "Temperature Shocks and Economic Growth: Evidence from the Last Half Century." *American Economic Journal: Macroeconomics* 4 (3): 66–95.

———. 2014. "What Do We Learn from the Weather? The New Climate-Economy Literature." *Journal of Economic Literature* 52 (3): 740–798.

Deressa, T. T., R. Hassan, C. Ringler, T. Alemu, and M. Yesuf. 2009. "Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia." *Global Environmental Change* 19 (2): 248–255.

Deschênes, O., and M. Greenstone. 2007. "The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather." *American Economic Review* 97 (1): 354–385.

Di Falco, S., M. Veronesi, and M. Yesuf. 2011. "Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia." *American Journal of Agricultural Economics* 93 (3): 829–846.

Endale, K., A. Pick, and T. Woldehanna. 2019. *Financing Social Protection in Ethiopia: A Long-term Perspective.* OECD Development Policy Papers. Paris: OECD.

FAO, IFAD, UNICEF, WFP, and WHO. 2018. *The State of Food Security and Nutrition in the World. Building climate resilience for food security and nutrition.* Rome: FAO.

FAO and Red Cross Red Crescent Climate Centre. 2019. *Managing climate risks through social protection – Reducing rural poverty and building resilient agricultural livelihoods.* Rome: FAO.

Gilligan, D., J. Hoddinott, and A. S. Taffesse. 2009. "The Impact of Ethiopia's Productive Safety Net Programme and its Linkages." *The Journal of Development Studies* 45 (10): 1684–1706.

Greene, W. 2005a. "Fixed and random effects in stochastic frontier models." *Journal of Productivity Analysis* 23:7–32.

———. 2005b. "Reconsidering heterogeneity in panel data estimators of the stochastic frontier model." *Journal of Econometrics* 126:269–303.

Hallegatte, S., M. Bangalore, L. Bonzanigo, M. Fay, T. Kane, U. Narloch, J. Rozenberg, D. Treguer, and A. Vogt-Schilb. 2016. *Shock Waves: Managing the Impacts of Climate Change on Poverty.* Climate Change and Development Series. Washington, DC: World Bank.

Hallegatte, S., A. Vogt-Schilb, M. Bangalore, and J. Rozenberg. 2017. *Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters.* Climate Change and Development Series. Washington, DC: World Bank.

Hennessy, D. 1998. "The production effects of agricultural income support policies under uncertainty." *American Journal of Agricultural Economics* 80 (1): 46–57.

Hidrobo, M., J. Hoddinott, N. Kumar, and M. Olivier. 2018. "Social Protection, Food Security, and Asset Formation." *World Development* 101:88–103.

Hirvonen, K., and J. Hoddinott. 2020. "Beneficiary Views on Cash and In-Kind Payments: Evidence from Ethiopia's Productive Safety Net Programme." *The World Bank Economic Review* lhaa002:1–16.

Hoddinott, J., G. Berhana, D. Gilligan, N. Kumar, and A. S. Taffesse. 2012. "The Impact of Ethiopia's Productive Safety Net Programme and Related Transfers on Agricultural Productivity." *Journal of African Economies* 21 (5): 761–786.

Hoddinott, J., and T. Mekasha. 2020. "Social Protection, Household Size, and Its Determinants: Evidence from Ethiopia." *The Journal of Development Studies* 56 (10): 1818–1837.

Hornbeck, R. 2012. "The enduring impact of the American Dust Bowl: Short- and long-run adjustments to environmental catastrophe." *American Economic Review* 102 (4): 1477–1507.

Hsiang, S. 2010. "Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America." *Proceedings of the National Academy of Sciences* 107 (35): 15367–15372.

Huang, C., and J.-T. Liu. 1994. "Estimation of a non-neutral stochastic frontier production function." *Journal of productivity analysis* 5 (2): 171–180.

Imbert, C., and J. Papp. 2015. "Labor market effects of social programs: Evidence from India's employment guarantee." *American Economic Journal: Applied Economics* 7 (2): 233–263.

Jacobsen, K. T. 2012. "In the eye of the storm. The welfare impacts of a Hurricane." *World Development* 40 (12): 2578–2589.

Johnson, D. 2014. "An assessment of pre- and within-season remotely sensed variables for forecasting corn and soybean yields in the United States." *Remote Sensing of Environment* 141 (5): 116–128.

Kellet, J., and A. Caravani. 2013. *Financing Disaster Risk Reduction. A 20 year story of international aid.* Research reports and studies. London: Overseas Development Institute, September.

Key, N., and S. Sneeringer. 2014. "Potential effect of cimate change on the productivity of US dairies." *American Journal of Agricultural Economics* 96 (4): 1136–1156.

Kumbhakar, S., S. Ghosh, and J. McGuckin. 1994. “A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms.” *Journal of Business and Economic Statistics* 9 (3): 279–286.

Kumbhakar, S., and C. A. K. Lovell. 2000. *Stochastic Frontier Analysis.* Cambridge: Cambridge University Press.

Kuriakose, A., R. Heltberg, W. Wiseman, C. Costella, R. Cipryk, and S. Cornelius. 2012. *Climate-responsive Social Protection.* Social Protection and Labor Discussion Paper 1210. Washington, DC: World Bank.

Lohmann, S., and T. Lechtenfeld. 2015. “The effect of drought on health outcomes and health expenditures in rural Vietnam.” *World Development* 72:432–448.

MaCurdy, T., and J. Pencavel. 1986. “Testing between competing models of wage and employment determination in unionized markets.” *Journal of Political Economy* 94 (3): 3–39.

Margolies, A., and J. Hoddinott. 2014. “Mapping the Impacts of Food Aid: Current Knowledge and Future Directions.” In *Food Security,* edited by M. Rosegrant, vol. 4: Food Policy for Food Security. Sage Publications: SAGE Library of International Security.

Meeusen, W., and J. van den Broeck. 1977. “Efficiency estimation from Cobb-Douglas production functions with composed error.” *International economic review* 18 (2): 435–444.

Moro, D., and P. Sckokai. 2013. “The impact of decoupled payments on farm choices: Conceptual and methodological challenges.” *FoodPolicy* 41:28–38.

Mueller, V., C. Gray, S. Handa, and D. Seidenfeld. 2020. “Do social protection programs foster short-term and long-term migration adaptation strategies?” *Environment and Development Economics* 25 (2): 135–158.

Mukherjee, D., B. E. Bravo-Ureta, and A. De Vries. 2012. “Potential effect of cimate change on the productivity of US dairies.” *The Australian Journal of Agricultural and Resource Economics* 57:123–140.

Muralidharan, K., P. Niehaus, and S. Sukhtankar. 2020. *General Equilibrium Effects of (Improving) Public Employment Programs: Experimental Evidence from India.* NBER Working Paper Series 23838. Cambridge, MA: National Bureau of Economic Research.

Patnaik, U., and P. K. Das. 2017. “Do Development Interventions Confer Adaptive Capacity? Insights from Rural India.” *World Development* 97:298–312.

Prifti, E., S. Daidone, N. Pace, and B. Davis. 2019. “Unconditional cash transfers, risk attitudes and modern inputs demand.” *Applied Econometrics* 53:100–118.

———. 2020. “Stuck exchange: Can cash transfers push smallholders out of autarky?” *The Journal of International Trade and Economic Development* 29 (5): 495–509.

Prifti, E., E. Estruch, S. Daidone, B. Davis, P. van Ufford, M. Stanfeld, S. Handa, D. Seidenfeld, and G. Tembo. 2017. “Learning About Labour Impacts of Cash Transfers in Zambia.” *Journal of African Economies* 26 (4): 433–442.

Rosenzweig, M., and C. Udry. 2014. “Rainfall Forecasts, Weather, and Wages over the Agricultural Production Cycle.” *American Economic Review: Papers and Proceedings* 104 (5): 2278–283.

Schubert, B. 2015. *Manual of Operations for the Social Cash Transfer Pilot Programs for Direct Support Clients.* Addis Ababa, Ethiopia: Regional States of Oromia, SNNPR Agencies of Labor, and Social Affairs.

Schwab, B. 2019. “Comparing the Productive Effects of Cash and Food Transfers in a Crisis Setting: Evidence from a Randomised Experiment in Yemen.” *The Journal of Development Studies* 55 (sup1): 29–54.

Shehu, A., and S. F. Sidique. 2015. “The effect of shocks on household consumption in rural Nigeria.” *The Journal of Developing Areas* 49 (3): 353–364.

Subbarao, K., C. del Ninno, C. Andrews, and C. Rodríguez-Alas. 2013. *Public Works as a Safety Net: Design, Evidence, and Implementation.* Washington DC: World Bank.

Taraz, V. 2017. “Adaptation to climate change: Historical evidence from the Indian monsoon.” *Environment and Development Economics* 22 (5): 517–545.

———. 2018. “Can farmers adapt to higher temperatures? Evidence from India.” *Environment and Development Economics* 112:205–219.

Tirivayi, N., M. Knowles, and B. Davis. 2016. “The interaction between social protection and agriculture: A review of evidence.” *Global Food Security* 10:52–62.

van Domelen, J., S. Coll-Black, L. Pelham, and J. Sandford. 2010. *Designing and implementing a rural safety net in a low income setting. Lessons Learned from Ethiopia's Productive Safety Net Program 2005–2009.* Washington DC: World Bank.

Wang, S., E. Ball, R. Nehring, R. Williams, and C. Truong. 2017. “Impacts of Climate Change and Extreme Weather on U.S. Agricultural Productivity: Evidence and Projection.” *NBER Working paper 23533.*

# 6 Tables and Figures

**Table 1: Summary statistics**

| | (1) Full sample | (2) No SA | (3) Public works | (4) Cash transfers | (5) Free food | (6) Multiple SA (2+) |
|---|---|---|---|---|---|---|
| Farm value of production (Birr) | 13583.06 | 14438.43 | 13708.83 | 11124.46* | 7113.16*** | 7066.02*** |
| | (57700.72) | (49347.15) | (126022.80) | (34674.77) | (15134.75) | (8567.33) |
| Income from sales (Birr) | 6616.12 | 6517.41 | 8587.8 | 8210.75 | 2903.61* | 4481.53 |
| | (50593.30) | (39097.17) | (123015.00) | (34159.33) | (4808.20) | (6944.73) |
| Monetary profits (Birr) | 3994.49 | 3610.55 | 6842.30* | 6292.74* | 1679.83 | 2783.18 |
| | (49458.77) | (37425.29) | (122387.90) | (33642.86) | (3967.83) | (7086.75) |
| Fertilizer quantity (kg) | 70.35 | 84.05 | 41.36 | 15.42** | 25.17 | 13.54*** |
| | (725.06) | (816.63) | (426.71) | (61.06) | (105.16) | (44.83) |
| Purchased seed (kg) | 12.72 | 13.79 | 8.52*** | 9.57** | 14.34 | 6.35*** |
| | (44.15) | (44.48) | (24.17) | (58.67) | (54.98) | (17.12) |
| Total labour (days) | 226.99 | 249.9 | 187.63*** | 132.03*** | 161.16*** | 115.34*** |
| | (436.37) | (483.98) | (208.03) | (209.18) | (238.98) | (143.14) |
| Hired labour expenditures (Birr) | 4399.86 | 5233.18 | 2849.34 | 856.93* | 890.41 | 1846.74 |
| | (60262.40) | (64347.33) | (72792.34) | (6501.59) | (10799.98) | (15954.21) |
| Land area (ha) | 1.24 | 1.36 | 0.89*** | 0.84*** | 0.79*** | 0.84*** |
| | (1.32) | (1.39) | (0.93) | (0.99) | (1.12) | (0.98) |
| NDVI long-run mean | 0.48 | 0.52 | 0.38*** | 0.39*** | 0.37*** | 0.32*** |
| | (0.15) | (0.14) | (0.12) | (0.14) | (0.11) | (0.10) |
| NDVI deviations from long-run mean | -0.16 | -0.1 | -0.32*** | -0.29*** | -0.40*** | -0.74*** |
| | (0.92) | (0.88) | (0.83) | (1.04) | (1.03) | (1.10) |
| Time to a large city (50,000 inhab.) | 4.32 | 4.34 | 3.24*** | 5.61*** | 3.31*** | 4.25 |
| | (2.66) | (2.55) | (2.05) | (3.57) | (2.13) | (2.63) |
| Agriculture asset index | 0.57 | 0.67 | 0.31*** | 0.25*** | 0.17*** | 0.20*** |
| | (1.25) | (1.27) | (1.07) | (1.16) | (1.30) | (1.18) |
| Share of land irrigated | 0.66 | 0.68 | 0.71** | 0.49*** | 0.65*** | 0.59*** |
| | (0.34) | (0.32) | (0.32) | (0.41) | (0.34) | (0.40) |
| Household size | 5.28 | 5.31 | 5.51** | 5.25 | 4.04*** | 5.52 |
| | (2.27) | (2.26) | (2.04) | (2.41) | (2.39) | (2.25) |
| Average years of education of household members | 1.99 | 2.11 | 1.66*** | 1.54*** | 1.57*** | 1.52*** |
| | (2.02) | (2.10) | (1.53) | (1.77) | (1.77) | (1.55) |
| Female headed household (1 if yes) | 0.23 | 0.21 | 0.22 | 0.29*** | 0.46*** | 0.28*** |
| | (0.42) | (0.41) | (0.42) | (0.45) | (0.50) | (0.45) |
| N | 9309 | 7124 | 802 | 736 | 321 | 326 |

Notes: N refers to the total number of observations. SA stands for social assistance. ***, **, * denote the statistical significance of the difference in means test vis-a-vis the No social assistance group at conventional 1, 5 and 10 % significance level. Standard deviations in parentheses

## Table 2: Inefficiency term - Farm income

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Agriculture asset index | -0.391*** | -0.391*** | -0.409*** | -0.408*** | -0.057*** | -0.056*** | -0.055*** | -0.054*** |
| | (0.066) | (0.066) | (0.059) | (0.059) | (0.012) | (0.013) | (0.013) | (0.013) |
| Irrigation | -1.033*** | -1.048*** | -1.141*** | -1.151*** | -0.311*** | -0.318*** | -0.306*** | -0.313*** |
| | (0.121) | (0.122) | (0.122) | (0.121) | (0.048) | (0.048) | (0.048) | (0.048) |
| Household Size | -0.088*** | -0.087*** | -0.077*** | -0.076*** | 0 | 0 | 0.001 | 0.001 |
| | (0.023) | (0.023) | (0.022) | (0.022) | (0.007) | (0.007) | (0.007) | (0.007) |
| Female-headed household (=1 if head is female) | 0.450*** | 0.453*** | 0.398*** | 0.401*** | 0.017 | 0.017 | 0.014 | 0.014 |
| | (0.085) | (0.085) | (0.085) | (0.085) | (0.044) | (0.044) | (0.044) | (0.044) |
| Average education | 0.035* | 0.036* | 0.035* | 0.035* | 0.013* | 0.014* | 0.012 | 0.012 |
| | (0.020) | (0.020) | (0.019) | (0.019) | (0.008) | (0.008) | (0.008) | (0.008) |
| Time to city (IHS) | 0.319*** | 0.313*** | 0.352*** | 0.347*** | 0.023 | 0.02 | 0.021 | 0.018 |
| | (0.072) | (0.073) | (0.071) | (0.072) | (0.028) | (0.028) | (0.028) | (0.028) |
| NDVI deviations (IHS) | -0.213*** | -0.144** | -0.214*** | -0.151** | -0.109*** | -0.087*** | -0.111*** | -0.088*** |
| | (0.053) | (0.059) | (0.053) | (0.059) | (0.019) | (0.021) | (0.019) | (0.021) |
| PSNP labour | 0.428*** | 0.313** | 0.408*** | 0.278** | 0.114*** | 0.073 | 0.112*** | 0.067 |
| | (0.113) | (0.122) | (0.115) | (0.125) | (0.043) | (0.044) | (0.043) | (0.044) |
| PSNP labour*NDVI deviations | | -0.248* | | -0.290* | | -0.107** | | -0.115** |
| | | (0.143) | | (0.149) | | (0.054) | | (0.053) |
| PSNP cash | -0.102 | -0.095 | -0.131 | -0.1 | -0.083 | -0.112 | -0.098 | -0.121* |
| | (0.142) | (0.160) | (0.146) | (0.165) | (0.068) | (0.070) | (0.068) | (0.071) |
| PSNP cash*NDVI deviations | | 0.026 | | 0.073 | | -0.071 | | -0.059 |
| | | (0.169) | | (0.177) | | (0.074) | | (0.076) |
| Free food | -0.07 | -0.253 | -0.004 | -0.145 | 0.087* | 0.05 | 0.095** | 0.058 |
| | (0.152) | (0.201) | (0.148) | (0.186) | (0.046) | (0.049) | (0.046) | (0.049) |
| Free food*NDVI deviations | | -0.353* | | -0.273 | | -0.055 | | -0.054 |
| | | (0.189) | | (0.179) | | (0.056) | | (0.057) |
| Constant | -0.764*** | -0.734*** | -0.823*** | -0.802*** | -0.081 | -0.066 | -0.086 | -0.07 |
| | (0.241) | (0.243) | (0.235) | (0.235) | (0.085) | (0.085) | (0.086) | (0.086) |
| **Frontier** | | | | | | | | |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Prices | | | | | | | | |
| Year dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Region dummies | ✓ | ✓ | ✓ | ✓ | | | | |
| Constant | ✓ | ✓ | ✓ | ✓ | | | | |
| Fixed effects | | | | | ✓ | ✓ | ✓ | ✓ |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors. CD stands for the Cobb-Douglas functional form whereas TLG stands for the translog functional form. The full regression can be found in the appendix. The inputs used in the production function are labour (number of days), seed (kg), fertilizer (kg) and land area (ha). As explained in the data section all inputs were transformed using the IHS transformation. The v-sigma equation is omitted from this table, but it includes land (ha) and labour (days) as determinants of the vsigma.

# Table 3: Sales

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture asset index | -0.190*** | -0.189*** | -0.185*** | -0.184*** | -0.195*** | -0.194*** | -0.189*** | -0.188*** | -0.044*** | -0.044*** | -0.042*** | -0.042*** | -0.044*** | -0.044*** | -0.043*** | -0.043*** |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Irrigation | -0.154** | -0.162** | -0.212*** | -0.218*** | -0.158** | -0.164** | -0.217*** | -0.222*** | -0.115*** | -0.118*** | -0.119*** | -0.122*** | -0.124*** | -0.125*** | -0.128*** | -0.130*** |
| | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.039) | (0.039) | (0.040) | (0.040) | (0.039) | (0.039) | (0.039) | (0.039) |
| Household Size | -0.091*** | -0.090*** | -0.084*** | -0.084*** | -0.095*** | -0.094*** | -0.089*** | -0.089*** | -0.020*** | -0.021*** | -0.020*** | -0.020*** | -0.021*** | -0.022*** | -0.021*** | -0.021*** |
| | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Female-headed household (=1 if head is female) | 0.315*** | 0.318*** | 0.309*** | 0.312*** | 0.312*** | 0.316*** | 0.307*** | 0.311*** | 0.117*** | 0.117*** | 0.117*** | 0.117*** | 0.111*** | 0.111*** | 0.110*** | 0.109*** |
| | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) |
| Average education | 0.037*** | 0.037*** | 0.040*** | 0.040*** | 0.039*** | 0.039*** | 0.043*** | 0.042*** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.007) | (0.007) | (0.007) | (0.007) | (0.006) | (0.006) | (0.006) | (0.007) |
| Time to city (IHS) | 0.252*** | 0.251*** | 0.257*** | 0.255*** | 0.266*** | 0.266*** | 0.271*** | 0.272*** | 0.124*** | 0.123*** | 0.124*** | 0.122*** | 0.128*** | 0.127*** | 0.127*** | 0.127*** |
| | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) |
| NDVI deviations (IHS) | -0.127*** | -0.098*** | -0.127*** | -0.102*** | -0.116*** | -0.090** | -0.115*** | -0.093** | -0.088*** | -0.080*** | -0.089*** | -0.081*** | -0.083*** | -0.077*** | -0.083*** | -0.078*** |
| | (0.034) | (0.038) | (0.034) | (0.038) | (0.034) | (0.038) | (0.034) | (0.038) | (0.017) | (0.018) | (0.017) | (0.018) | (0.016) | (0.018) | (0.017) | (0.018) |
| PSNP labour | 0.150** | 0.081 | 0.137* | 0.062 | 0.145** | 0.08 | 0.131* | 0.061 | 0.065* | 0.032 | 0.065* | 0.029 | 0.061 | 0.034 | 0.06 | 0.03 |
| | (0.072) | (0.079) | (0.073) | (0.080) | (0.072) | (0.079) | (0.073) | (0.080) | (0.039) | (0.043) | (0.040) | (0.043) | (0.039) | (0.043) | (0.039) | (0.043) |
| PSNP labour*NDVI deviations | | -0.173* | | -0.194* | | -0.157 | | -0.175* | | -0.09 | | -0.098 | | -0.075 | | -0.081 |
| | | (0.099) | | (0.100) | | (0.100) | | (0.101) | | (0.059) | | (0.060) | | (0.059) | | (0.059) |
| PSNP cash | 0.054 | 0.095 | 0.032 | 0.078 | 0.049 | 0.106 | 0.027 | 0.089 | 0.031 | 0.045 | 0.027 | 0.041 | 0.031 | 0.045 | 0.024 | 0.041 |
| | (0.106) | (0.115) | (0.106) | (0.115) | (0.106) | (0.114) | (0.106) | (0.114) | (0.055) | (0.058) | (0.055) | (0.058) | (0.054) | (0.057) | (0.054) | (0.057) |
| PSNP cash*NDVI deviations | | 0.103 | | 0.117 | | 0.156 | | 0.17 | | 0.029 | | 0.033 | | 0.032 | | 0.04 |
| | | (0.123) | | (0.123) | | (0.122) | | (0.122) | | (0.072) | | (0.073) | | (0.072) | | (0.072) |
| Free food | -0.330*** | -0.403*** | -0.310*** | -0.370*** | -0.404*** | -0.483*** | -0.386*** | -0.451*** | -0.031 | -0.039 | -0.036 | -0.044 | -0.048 | -0.052 | -0.053 | -0.057 |
| | (0.083) | (0.095) | (0.082) | (0.093) | (0.085) | (0.098) | (0.084) | (0.096) | (0.042) | (0.045) | (0.042) | (0.046) | (0.041) | (0.045) | (0.042) | (0.046) |
| Free food*NDVI deviations | | -0.161 | | -0.123 | | -0.18 | | -0.143 | | -0.007 | | -0.004 | | 0 | | 0.001 |
| | | (0.108) | | (0.105) | | (0.112) | | (0.109) | | (0.049) | | (0.049) | | (0.048) | | (0.048) |
| Constant | 1.488*** | 1.492*** | 1.454*** | 1.459*** | 1.496*** | 1.495*** | 1.462*** | 1.461*** | 0.572*** | 0.579*** | 0.569*** | 0.576*** | 0.570*** | 0.575*** | 0.571*** | 0.576*** |
| | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.070) | (0.071) | (0.071) | (0.072) | (0.069) | (0.070) | (0.070) | (0.070) |
| **Frontier** | | | | | | | | | | | | | | | | |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Prices | | | | | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | ✓ | ✓ |
| Year dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Constant | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Fixed effects | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors. CD stands for the Cobb-Douglas functional form whereas TLG stands for the translog functional form. The full regression can be found in the appendix. The inputs used in the production function are labour (number of days), seed (kg), fertilizer (kg) and land area (ha). As explained in the data section all inputs were transformed using the IHS transformation. The v-sigma equation is omitted from this table, but it includes land (ha) and labour (days) as determinants of the vsigma.

## Table 4: Profits

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture asset index | -0.033* | -0.032* | -0.035* | -0.034* | -0.029* | -0.029 | -0.031* | -0.030* | 0.018 | 0.018 | 0.019* | 0.019* | 0.019* | 0.020* |
| | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Irrigation | 0.103* | 0.098 | 0.105* | 0.1 | 0.085 | 0.081 | 0.087 | 0.082 | -0.015 | -0.019 | -0.013 | -0.017 | -0.019 | -0.019 |
| | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.041) | (0.041) | (0.041) | (0.041) | (0.041) | (0.041) |
| Household Size | -0.041*** | -0.040*** | -0.043*** | -0.042*** | -0.038*** | -0.037*** | -0.040*** | -0.039*** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Female-headed household (=1 if head is female) | 0.059 | 0.061 | 0.058 | 0.061 | 0.053 | 0.055 | 0.052 | 0.055 | -0.037 | -0.037 | -0.035 | -0.035 | -0.036 | -0.035 |
| | (0.047) | (0.047) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) |
| Average education | 0.070*** | 0.070*** | 0.070*** | 0.071*** | 0.071*** | 0.071*** | 0.071*** | 0.072*** | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Time to city (IHS) | -0.044 | -0.041 | -0.04 | -0.037 | -0.044 | -0.041 | -0.039 | -0.036 | -0.035 | -0.034 | -0.035 | -0.034 | -0.032 | -0.032 |
| | (0.033) | (0.033) | (0.033) | (0.034) | (0.033) | (0.033) | (0.033) | (0.034) | (0.023) | (0.023) | (0.023) | (0.023) | (0.024) | (0.023) |
| NDVI deviations (IHS) | -0.119*** | -0.104*** | -0.119*** | -0.103*** | -0.120*** | -0.105*** | -0.120*** | -0.105*** | -0.078*** | -0.068*** | -0.080*** | -0.070*** | -0.070*** | -0.072*** |
| | (0.028) | (0.031) | (0.029) | (0.031) | (0.028) | (0.031) | (0.029) | (0.032) | (0.017) | (0.019) | (0.017) | (0.019) | (0.019) | (0.019) |
| PSNP labour | -0.110* | -0.152** | -0.111* | -0.154** | -0.115* | -0.159** | -0.115* | -0.161** | -0.008 | -0.032 | -0.009 | -0.033 | -0.031 | -0.031 |
| | (0.064) | (0.072) | (0.064) | (0.072) | (0.064) | (0.072) | (0.064) | (0.072) | (0.041) | (0.043) | (0.041) | (0.043) | (0.043) | (0.044) |
| PSNP cash | -0.415*** | -0.347*** | -0.420*** | -0.346*** | -0.422*** | -0.352*** | -0.427*** | -0.351*** | -0.164*** | -0.140** | -0.169*** | -0.144** | -0.141** | -0.145** |
| | (0.090) | (0.096) | (0.091) | (0.096) | (0.091) | (0.097) | (0.091) | (0.096) | (0.059) | (0.064) | (0.059) | (0.063) | (0.064) | (0.063) |
| Free food | -0.431*** | -0.499*** | -0.464*** | -0.538*** | -0.417*** | -0.482*** | -0.451*** | -0.522*** | -0.138*** | -0.174*** | -0.141*** | -0.175*** | -0.172*** | -0.175*** |
| | (0.076) | (0.086) | (0.076) | (0.087) | (0.076) | (0.086) | (0.076) | (0.087) | (0.041) | (0.044) | (0.041) | (0.044) | (0.044) | (0.044) |
| PSNP labour*NDVI deviations | | -0.08 | | -0.078 | | -0.088 | | -0.087 | | -0.058 | | -0.057 | -0.059 | -0.058 |
| | | (0.094) | | (0.095) | | (0.094) | | (0.095) | | (0.052) | | (0.052) | (0.052) | (0.052) |
| PSNP cash*NDVI deviations | | 0.228** | | 0.253** | | 0.233** | | 0.257** | | 0.073 | | 0.073 | 0.074 | 0.075 |
| | | (0.111) | | (0.110) | | (0.111) | | (0.111) | | (0.070) | | (0.070) | (0.070) | (0.070) |
| Free food*NDVI deviations | | -0.186* | | -0.206** | | -0.177* | | -0.195** | | -0.079 | | -0.072 | -0.076 | -0.071 |
| | | (0.096) | | (0.098) | | (0.095) | | (0.097) | | (0.050) | | (0.049) | (0.050) | (0.050) |
| Constant | 3.855*** | 3.848*** | 3.857*** | 3.849*** | 3.841*** | 3.835*** | 3.841*** | 3.833*** | 1.812*** | 1.812*** | 1.805*** | 1.805*** | 1.806*** | 1.800*** |
| | (0.105) | (0.105) | (0.106) | (0.106) | (0.105) | (0.105) | (0.106) | (0.106) | (0.074) | (0.074) | (0.074) | (0.074) | (0.075) | (0.074) |
| **Frontier** | | | | | | | | | | | | | | |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG | CD | CD | CD | CD | TLG | TLG |
| Prices | | | | | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | ✓ |
| Year dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| Constant | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| Fixed effects | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 |

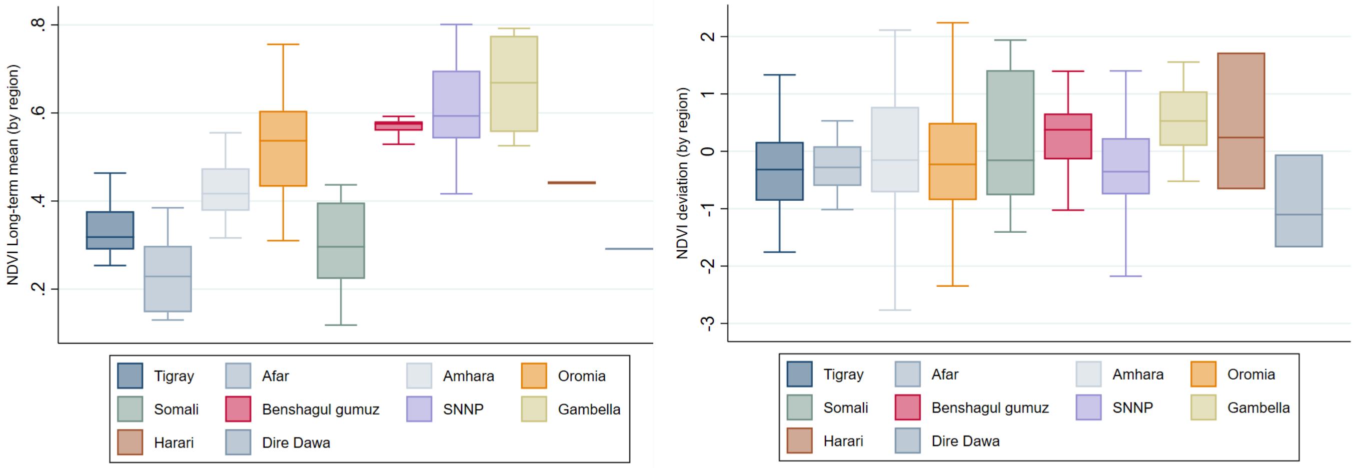
Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors. CD stands for the Cobb-Douglas functional form whereas TLG stands for the translog functional form. The full regression can be found in the appendix. The inputs used in the production function are labour (number of days), seed (kg), fertilizer (kg) and land area (ha). As explained in the data section all inputs were transformed using the IHS transformation. The v-sigma equation is omitted from this table, but it includes land (ha) and labour (days) as determinants of the vsigma.

# 7 Supplementary material

## Table S1: Variable description

| | Variable | Description |
|---|---|---|
| **Outcome variables** | Farm value of production (Birr) | Total value of production of crops, livestock and livestock by-products in Birr. This variable includes the sales of these products and values non-market uses of these products (self-consumption) at market value. |
| | Income from sales (Birr) | Total income from sales of crops, livestock and livestock by-products in Birr. |
| | Monetary profits (Birr) | Total income from sales of crops, livestock and livestock by-products minus the cost of all purchased inputs (seed, fertilizer, land rental, livestock purchase, feed, etc...). The value is expressed in Birr. |
| **Inputs** | Fertilizer quantity (kg) | Total quantity of fertilizer used (in kg) |
| | Purchased seed (kg) | Total quantity of purchased seed (kg) |
| | Total labour (days) | Total number of days worked by household and hired labour |
| | Hired labour expenditures (Birr) | Total expenditures related to hired labour incurred by the household |
| | Land area (ha) | Total land area measured by GPS. Whenever GPS estimates were not available, the self-reported land size was used |
| | Labour (IHS) | Inverse Hyperbolic Sine (IHS) transformation of the total number of days of labour used (household and hired) by the household |
| | Seed (IHS) | Inverse Hyperbolic Sine (IHS) transformation of the total amount of purchased seed |
| | Fertilizer (IHS) | Inverse Hyperbolic Sine (IHS) transformation of the total amount of fertilizer used |
| | Land (Ha) (IHS) | Inverse Hyperbolic Sine (IHS) transformatoin of the total amount of land |
| **Weather** | NDVI long-run mean | Long run mean value of the NDVI. Since the NDVI series is only available from 2000, the mean between 2000 and the most recent year is used |
| | NDVI deviations from long-run mean | Deviations between the observed NDVI and its long-term mean. In the study we use the Woreda-level average of the NDVI observed monthly at a resolution of 1km. |
| | CHIRPS deviations | Deviations in annual rainfall, compiled using the CHIRPS database (used to test the sensitivity of the results to alternative weather indices). In the study we use the Woreda-level average of precipitation observed at high resolution (i.e. 0.05°). |
| **Social Assistance** | PSNP labour | Dummy variable taking the value of 1 if the household participates in a public work scheme under the PSNP |
| | PSNP cash | Dummy variable taking the value of 1 if the household participates in a cash transfer under the PSNP |
| | Free food | Dummy variable taking the value of 1 if the household receives free food |
| **Det. Inefficiency** | Time to a large city (50,000 inhab.) | Number of hours needed to reach a city with at least 50 000 inhabitants |
| | Agriculture asset index | The agriculture asset index is derived using Principal Component Analysis (PCA). More specifically, it is the result of the predicted values of the first component. The variables included in the index are the number of sickles, axes, pick axes, traditional ploughs, modern ploughs and water pumps |
| | Share of land irrigated | Share of the land that is irrigated (%) |
| | Household size | Total number of household members |
| | Average years of education of household members | Average year of education of household members |
| | Female headed household (1 if yes) | Dummy variable taking the value of 1 if the household is headed by a female |
| **Wave** | Year 2013 | Dummy variable taking the value of 1 if the the observation is in wave 2 (in 2013). 2011 is the excluded dummy variable |
| | Year 2015 | Dummy variable taking the value of 1 if the the observation is in wave 3 (in 2015). 2011 is the excluded dummy variable. |

**Figure S1: NDVI by region**




(a) Long-run NDVI by region

(b) NDVI deviations by region

## Table S2: Farm income - Full

| **Frontier** | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.279*** | 0.279*** | -0.176*** | -0.174*** | 0.214*** | 0.213*** | 0.158*** | 0.155*** |
| | (0.014) | (0.014) | (0.040) | (0.040) | (0.014) | (0.014) | (0.054) | (0.054) |
| Seed (IHS) | 0 | 0 | -0.019 | -0.02 | 0.001 | 0.001 | 0.031 | 0.029 |
| | (0.006) | (0.006) | (0.044) | (0.044) | (0.007) | (0.007) | (0.044) | (0.044) |
| Fertilizer (IHS) | 0.072*** | 0.071*** | 0.226*** | 0.224*** | 0.041*** | 0.040*** | 0.140*** | 0.138*** |
| | (0.006) | (0.006) | (0.040) | (0.040) | (0.006) | (0.006) | (0.036) | (0.036) |
| Land (Ha) (IHS) | 0.636*** | 0.636*** | 1.445*** | 1.447*** | 0.327*** | 0.328*** | 0.711*** | 0.719*** |
| | (0.023) | (0.023) | (0.119) | (0.119) | (0.033) | (0.033) | (0.128) | (0.128) |
| Year 2013 | 0.279*** | 0.279*** | 0.256*** | 0.256*** | 0.225*** | 0.226*** | 0.227*** | 0.227*** |
| | (0.030) | (0.030) | (0.030) | (0.030) | (0.026) | (0.026) | (0.027) | (0.027) |
| Year 2015 | 0.393*** | 0.397*** | 0.393*** | 0.396*** | 0.380*** | 0.385*** | 0.380*** | 0.386*** |
| | (0.028) | (0.028) | (0.028) | (0.028) | (0.023) | (0.023) | (0.023) | (0.023) |
| Labour*labour | | | 0.051*** | 0.051*** | | | 0.006 | 0.007 |
| | | | (0.005) | (0.005) | | | (0.005) | (0.005) |
| Seed*Seed | | | 0.018*** | 0.018*** | | | 0.010** | 0.010** |
| | | | (0.004) | (0.004) | | | (0.004) | (0.004) |
| Fert*Fert | | | 0.003 | 0.004 | | | -0.001 | -0.001 |
| | | | (0.003) | (0.003) | | | (0.003) | (0.003) |
| Land*Land | | | -0.229*** | -0.231*** | | | -0.193*** | -0.194*** |
| | | | (0.030) | (0.030) | | | (0.037) | (0.037) |
| Land*Labour | | | -0.047** | -0.046** | | | 0.017 | 0.016 |
| | | | (0.023) | (0.023) | | | (0.020) | (0.020) |
| Land*Seed | | | 0.027** | 0.026** | | | 0.012 | 0.011 |
| | | | (0.011) | (0.011) | | | (0.011) | (0.011) |
| Land*Fertilizer | | | -0.014 | -0.013 | | | -0.008 | -0.008 |
| | | | (0.009) | (0.009) | | | (0.008) | (0.008) |
| Labour*Seed | | | -0.015** | -0.015* | | | -0.014* | -0.013* |
| | | | (0.008) | (0.008) | | | (0.007) | (0.007) |
| Labou*Fert | | | -0.026*** | -0.026*** | | | -0.013** | -0.013** |
| | | | (0.007) | (0.007) | | | (0.006) | (0.006) |
| Seed*Fert | | | -0.001 | -0.001 | | | -0.002 | -0.002 |
| | | | (0.002) | (0.002) | | | (0.002) | (0.002) |
| Constant | 6.008*** | 6.015*** | 6.695*** | 6.697*** | | | | |
| | (0.095) | (0.095) | (0.121) | (0.122) | | | | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | | | | |
| **Usigma** | | | | | | | | |
| Agriculture asset index | -0.391*** | -0.391*** | -0.409*** | -0.408*** | -0.057*** | -0.056*** | -0.055*** | -0.054*** |
| | (0.066) | (0.066) | (0.059) | (0.059) | (0.012) | (0.013) | (0.013) | (0.013) |
| Irrigation | -1.033*** | -1.048*** | -1.141*** | -1.151*** | -0.311*** | -0.318*** | -0.306*** | -0.313*** |
| | (0.121) | (0.122) | (0.122) | (0.121) | (0.048) | (0.048) | (0.048) | (0.048) |
| Household Size | -0.088*** | -0.087*** | -0.077*** | -0.076*** | 0 | 0 | 0.001 | 0.001 |
| | (0.023) | (0.023) | (0.022) | (0.022) | (0.007) | (0.007) | (0.007) | (0.007) |
| Female-headed household (1 if head is female) | 0.450*** | 0.453*** | 0.398*** | 0.401*** | 0.017 | 0.017 | 0.014 | 0.014 |
| | (0.085) | (0.085) | (0.085) | (0.085) | (0.044) | (0.044) | (0.044) | (0.044) |
| Average education | 0.035* | 0.036* | 0.035* | 0.035* | 0.013* | 0.014* | 0.012 | 0.012 |
| | (0.020) | (0.020) | (0.019) | (0.019) | (0.008) | (0.008) | (0.008) | (0.008) |
| Time to city (IHS) | 0.319*** | 0.313*** | 0.352*** | 0.347*** | 0.023 | 0.02 | 0.021 | 0.018 |
| | (0.072) | (0.073) | (0.071) | (0.072) | (0.028) | (0.028) | (0.028) | (0.028) |
| NDVI deviations (IHS) | -0.213*** | -0.144** | -0.214*** | -0.151** | -0.109*** | -0.087*** | -0.111*** | -0.088*** |
| | (0.053) | (0.059) | (0.053) | (0.059) | (0.019) | (0.021) | (0.019) | (0.021) |
| PSNP labour | 0.428*** | 0.313** | 0.408*** | 0.278** | 0.114*** | 0.073 | 0.112*** | 0.067 |
| | (0.113) | (0.122) | (0.115) | (0.125) | (0.043) | (0.044) | (0.043) | (0.044) |
| PSNP labour*NDVI deviations | | -0.248* | | -0.290* | | -0.107** | | -0.115** |
| | | (0.143) | | (0.149) | | (0.054) | | (0.053) |
| PSNP cash | -0.102 | -0.095 | -0.131 | -0.1 | -0.083 | -0.112 | -0.098 | -0.121* |
| | (0.142) | (0.160) | (0.146) | (0.165) | (0.068) | (0.070) | (0.068) | (0.071) |
| PSNP cash*NDVI deviations | | 0.026 | | 0.073 | | -0.071 | | -0.059 |
| | | (0.169) | | (0.177) | | (0.074) | | (0.076) |
| Free food | -0.07 | -0.253 | -0.004 | -0.145 | 0.087* | 0.05 | 0.095** | 0.058 |
| | (0.152) | (0.201) | (0.148) | (0.186) | (0.046) | (0.049) | (0.046) | (0.049) |
| Free food*NDVI deviations | | -0.353* | | -0.273 | | -0.055 | | -0.054 |
| | | (0.189) | | (0.179) | | (0.056) | | (0.057) |
| Constant | -0.764*** | -0.734*** | -0.823*** | -0.802*** | -0.081 | -0.066 | -0.086 | -0.07 |
| | (0.241) | (0.243) | (0.235) | (0.235) | (0.085) | (0.085) | (0.086) | (0.086) |
| **Vsigma** | | | | | | | | |
| Land (Ha) (IHS) | -0.135* | -0.129* | -0.133** | -0.128* | -0.466*** | -0.475*** | -0.468*** | -0.479*** |
| | (0.070) | (0.071) | (0.066) | (0.067) | (0.092) | (0.093) | (0.094) | (0.095) |
| Labour (IHS) | -0.258*** | -0.260*** | -0.213*** | -0.215*** | -0.182*** | -0.183*** | -0.186*** | -0.187*** |
| | (0.019) | (0.020) | (0.021) | (0.021) | (0.018) | (0.018) | (0.019) | (0.019) |
| Constant | 1.282*** | 1.287*** | 1.007*** | 1.016*** | 0.491*** | 0.500*** | 0.502*** | 0.509*** |
| | (0.090) | (0.090) | (0.103) | (0.102) | (0.072) | (0.072) | (0.074) | (0.073) |
| Number of observations | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

# Table S3: Sales full

| Frontier | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.099*** | 0.099*** | -0.453*** | -0.452*** | 0.097*** | 0.098*** | -0.453*** | -0.452*** | 0.138*** | 0.137*** | -0.197*** | -0.202*** | 0.135*** | 0.134*** | -0.194*** | -0.199*** |
| | (0.017) | (0.017) | (0.045) | (0.045) | (0.017) | (0.017) | (0.043) | (0.043) | (0.023) | (0.023) | (0.073) | (0.073) | (0.022) | (0.022) | (0.070) | (0.070) |
| Seed (IHS) | 0.008 | 0.008 | 0.044 | 0.046 | 0.019** | 0.019** | 0.064 | 0.066 | 0.019 | 0.019 | 0.143* | 0.146* | 0.024* | 0.024* | 0.112 | 0.116 |
| | (0.009) | (0.009) | (0.059) | (0.059) | (0.009) | (0.009) | (0.059) | (0.059) | (0.013) | (0.013) | (0.080) | (0.079) | (0.013) | (0.013) | (0.077) | (0.077) |
| Fertilizer (IHS) | 0.034*** | 0.034*** | 0.112* | 0.112* | 0.022** | 0.021** | 0.107* | 0.106* | 0.016 | 0.016 | 0.061 | 0.061 | 0.01 | 0.009 | 0.081 | 0.08 |
| | (0.009) | (0.009) | (0.058) | (0.058) | (0.009) | (0.009) | (0.057) | (0.057) | (0.010) | (0.010) | (0.062) | (0.062) | (0.011) | (0.011) | (0.059) | (0.059) |
| Land (Ha) (IHS) | 0.616*** | 0.618*** | 1.336*** | 1.338*** | 0.561*** | 0.562*** | 1.175*** | 1.176*** | 0.408*** | 0.409*** | 0.551** | 0.562*** | 0.404*** | 0.405*** | 0.562*** | 0.574*** |
| | (0.032) | (0.032) | (0.168) | (0.169) | (0.032) | (0.032) | (0.167) | (0.167) | (0.059) | (0.059) | (0.217) | (0.218) | (0.059) | (0.059) | (0.209) | (0.209) |
| Year 2013 | 0.298*** | 0.295*** | 0.266*** | 0.263*** | 0.044 | 0.041 | -0.018 | -0.022 | 0.359*** | 0.358*** | 0.368*** | 0.365*** | 0.231*** | 0.229*** | 0.237*** | 0.235*** |
| | (0.043) | (0.043) | (0.045) | (0.045) | (0.075) | (0.075) | (0.076) | (0.076) | (0.044) | (0.044) | (0.046) | (0.046) | (0.083) | (0.083) | (0.084) | (0.084) |
| Year 2015 | 0.866*** | 0.869*** | 0.854*** | 0.857*** | 0.646*** | 0.648*** | 0.614*** | 0.616*** | 0.768*** | 0.771*** | 0.768*** | 0.772*** | 0.328** | 0.335** | 0.314** | 0.321** |
| | (0.042) | (0.042) | (0.042) | (0.042) | (0.121) | (0.121) | (0.121) | (0.121) | (0.039) | (0.040) | (0.041) | (0.041) | (0.143) | (0.142) | (0.142) | (0.142) |
| Labour*labour | | | 0.073*** | 0.073*** | | | 0.071*** | 0.071*** | | | 0.032*** | 0.032*** | | | 0.030*** | 0.030*** |
| | | | (0.007) | (0.007) | | | (0.007) | (0.007) | | | (0.009) | (0.009) | | | (0.008) | (0.008) |
| Seed*Seed | | | 0.011* | 0.011* | | | 0.009* | 0.009 | | | -0.006 | -0.006 | | | -0.005 | -0.005 |
| | | | (0.006) | (0.006) | | | (0.006) | (0.006) | | | (0.008) | (0.008) | | | (0.008) | (0.008) |
| Fert*Fert | | | 0.001 | 0.001 | | | -0.002 | -0.002 | | | -0.003 | -0.003 | | | -0.005 | -0.005 |
| | | | (0.005) | (0.005) | | | (0.005) | (0.005) | | | (0.005) | (0.005) | | | (0.005) | (0.005) |
| Land*Land | | | -0.083* | -0.085* | | | -0.090** | -0.093** | | | -0.179*** | -0.183*** | | | -0.241*** | -0.243*** |
| | | | (0.045) | (0.045) | | | (0.043) | (0.044) | | | (0.067) | (0.067) | | | (0.065) | (0.065) |
| Land*Labour | | | -0.096*** | -0.095*** | | | -0.076** | -0.075** | | | 0.053 | 0.053 | | | 0.073** | 0.072** |
| | | | (0.034) | (0.034) | | | (0.033) | (0.033) | | | (0.036) | (0.036) | | | (0.034) | (0.035) |
| Land*Seed | | | 0.038** | 0.037** | | | 0.032** | 0.032** | | | 0.007 | 0.007 | | | -0.016 | -0.016 |
| | | | (0.016) | (0.016) | | | (0.016) | (0.016) | | | (0.021) | (0.021) | | | (0.020) | (0.020) |
| Land*Fertilizer | | | -0.036*** | -0.036*** | | | -0.027** | -0.027** | | | -0.019 | -0.019 | | | 0.01 | 0.01 |
| | | | (0.014) | (0.014) | | | (0.014) | (0.014) | | | (0.014) | (0.014) | | | (0.014) | (0.014) |
| Labour*Seed | | | -0.023** | -0.023** | | | -0.021** | -0.022** | | | -0.019 | -0.019 | | | -0.009 | -0.009 |
| | | | (0.010) | (0.010) | | | (0.010) | (0.010) | | | (0.013) | (0.013) | | | (0.013) | (0.013) |
| Labour*Fert | | | -0.009 | -0.009 | | | -0.009 | -0.009 | | | -0.002 | -0.002 | | | -0.009 | -0.009 |
| | | | (0.010) | (0.010) | | | (0.010) | (0.010) | | | (0.011) | (0.011) | | | (0.010) | (0.010) |
| Seed*Fert | | | 0.005 | 0.005 | | | 0.003 | 0.003 | | | 0.005 | 0.005 | | | 0.003 | 0.002 |
| | | | (0.004) | (0.004) | | | (0.003) | (0.003) | | | (0.004) | (0.004) | | | (0.004) | (0.004) |
| Price Sorghum | | | | | -0.011 | 0.001 | -0.009 | 0.002 | | | | | 0.151 | 0.162 | 0.174 | 0.183* |
| | | | | | (0.092) | (0.092) | (0.093) | (0.093) | | | | | (0.107) | (0.106) | (0.107) | (0.107) |
| Price Teff | | | | | -0.180*** | -0.182*** | -0.204*** | -0.206*** | | | | | 0.056 | 0.058 | 0.038 | 0.041 |
| | | | | | (0.057) | (0.057) | (0.057) | (0.057) | | | | | (0.075) | (0.075) | (0.075) | (0.075) |
| Price Wheat | | | | | -0.257** | -0.255** | -0.204** | -0.202** | | | | | -0.338*** | -0.336*** | -0.312** | -0.309** |
| | | | | | (0.100) | (0.100) | (0.100) | (0.100) | | | | | (0.121) | (0.121) | (0.122) | (0.122) |
| Price Sesame | | | | | 0.344*** | 0.342*** | 0.386*** | 0.385*** | | | | | 0.264** | 0.263** | 0.289** | 0.288** |
| | | | | | (0.100) | (0.100) | (0.100) | (0.100) | | | | | (0.114) | (0.114) | (0.114) | (0.114) |
| Price Lentils | | | | | 0.357*** | 0.361*** | 0.337*** | 0.340*** | | | | | 0.643*** | 0.641*** | 0.648*** | 0.646*** |
| | | | | | (0.122) | (0.123) | (0.124) | (0.124) | | | | | (0.150) | (0.150) | (0.149) | (0.149) |
| Price Chat | | | | | -0.061** | -0.064** | -0.048* | -0.050* | | | | | -0.039 | -0.041 | -0.024 | -0.026 |
| | | | | | (0.028) | (0.028) | (0.028) | (0.028) | | | | | (0.035) | (0.035) | (0.035) | (0.035) |
| Price Coffee | | | | | 0.028 | 0.028 | -0.009 | -0.009 | | | | | -0.039 | -0.038 | -0.049 | -0.047 |
| | | | | | (0.043) | (0.043) | (0.043) | (0.043) | | | | | (0.051) | (0.051) | (0.051) | (0.051) |
| Price large ruminants | | | | | 0.119*** | 0.118*** | 0.117*** | 0.117*** | | | | | 0.097*** | 0.096*** | 0.103*** | 0.102*** |
| | | | | | (0.020) | (0.020) | (0.019) | (0.019) | | | | | (0.020) | (0.021) | (0.021) | (0.021) |
| Price small ruminants | | | | | 0.141** | 0.142** | 0.150*** | 0.151*** | | | | | 0.043 | 0.042 | 0.056 | 0.055 |
| | | | | | (0.057) | (0.056) | (0.056) | (0.056) | | | | | (0.048) | (0.048) | (0.049) | (0.049) |
| Price poultry | | | | | 0.175*** | 0.175*** | 0.161** | 0.161** | | | | | -0.012 | -0.015 | -0.035 | -0.038 |
| | | | | | (0.067) | (0.067) | (0.066) | (0.066) | | | | | (0.057) | (0.057) | (0.057) | (0.057) |
| Price Milk | | | | | -0.024 | -0.025 | -0.015 | -0.016 | | | | | 0.069** | 0.067* | 0.079** | 0.077** |
| | | | | | (0.030) | (0.030) | (0.029) | (0.029) | | | | | (0.034) | (0.034) | (0.034) | (0.034) |
| Constant | 7.048*** | 7.050*** | 7.734*** | 7.738*** | 4.376*** | 4.368*** | 5.112*** | 5.105*** | | | | | | | | |
| | (0.116) | (0.116) | (0.123) | (0.124) | (0.307) | (0.307) | (0.304) | (0.304) | | | | | | | | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Usigma | | | | | | | | | | | | | | | | |
| Agriculture asset index | -0.190*** | -0.189*** | -0.185*** | -0.184*** | -0.195*** | -0.194*** | -0.189*** | -0.188*** | -0.044*** | -0.044*** | -0.042*** | -0.042*** | -0.044*** | -0.044*** | -0.043*** | -0.043*** |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Irrigation | -0.154** | -0.162** | -0.212*** | -0.218*** | -0.158** | -0.164** | -0.217*** | -0.222*** | -0.115*** | -0.118*** | -0.119*** | -0.122*** | -0.124*** | -0.125*** | -0.128*** | -0.130*** |
| | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.039) | (0.039) | (0.040) | (0.040) | (0.039) | (0.039) | (0.039) | (0.039) |
| Household Size | -0.091*** | -0.090*** | -0.084*** | -0.084*** | -0.095*** | -0.094*** | -0.089*** | -0.089*** | -0.020*** | -0.021*** | -0.020*** | -0.020*** | -0.021*** | -0.022*** | -0.021*** | -0.021*** |
| | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Female-headed household | 0.315*** | 0.318*** | 0.309*** | 0.312*** | 0.312*** | 0.316*** | 0.307*** | 0.311*** | 0.117*** | 0.117*** | 0.117*** | 0.117*** | 0.111*** | 0.111*** | 0.110*** | 0.109*** |
| | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.057) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) |
| Average education | 0.037*** | 0.037*** | 0.040*** | 0.040*** | 0.039*** | 0.039*** | 0.043*** | 0.042*** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.007) | (0.007) | (0.007) | (0.007) | (0.006) | (0.006) | (0.006) | (0.007) |
| Time to city (IHS) | 0.252*** | 0.251*** | 0.257*** | 0.255*** | 0.266*** | 0.266*** | 0.271*** | 0.272*** | 0.124*** | 0.123*** | 0.124*** | 0.122*** | 0.128*** | 0.127*** | 0.127*** | 0.127*** |
| | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.043) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) | (0.023) |
| NDVI deviations (IHS) | -0.127*** | -0.098*** | -0.127*** | -0.102*** | -0.116*** | -0.090** | -0.115*** | -0.093** | -0.088*** | -0.080*** | -0.089*** | -0.081*** | -0.083*** | -0.077*** | -0.083*** | -0.078*** |
| | (0.034) | (0.038) | (0.034) | (0.038) | (0.034) | (0.038) | (0.034) | (0.038) | (0.017) | (0.018) | (0.017) | (0.018) | (0.016) | (0.018) | (0.017) | (0.018) |
| PSNP labour | 0.150** | 0.081 | 0.137* | 0.062 | 0.145** | 0.08 | 0.131* | 0.061 | 0.065* | 0.032 | 0.065* | 0.029 | 0.061 | 0.034 | 0.06 | 0.03 |
| | (0.072) | (0.079) | (0.073) | (0.080) | (0.072) | (0.079) | (0.073) | (0.080) | (0.039) | (0.043) | (0.040) | (0.043) | (0.039) | (0.043) | (0.039) | (0.043) |
| PSNP labour*NDVI deviations | | -0.173* | | -0.194* | | -0.157 | | -0.175* | | -0.09 | | -0.098 | | -0.075 | | -0.081 |
| | | (0.099) | | (0.100) | | (0.100) | | (0.101) | | (0.059) | | (0.060) | | (0.059) | | (0.059) |
| PSNP cash | 0.054 | 0.095 | 0.032 | 0.078 | 0.049 | 0.106 | 0.027 | 0.089 | 0.031 | 0.045 | 0.027 | 0.041 | 0.031 | 0.045 | 0.024 | 0.041 |
| | (0.106) | (0.115) | (0.106) | (0.115) | (0.106) | (0.114) | (0.106) | (0.114) | (0.055) | (0.058) | (0.055) | (0.058) | (0.054) | (0.057) | (0.054) | (0.057) |
| PSNP cash*NDVI deviations | | 0.103 | | 0.117 | | 0.156 | | 0.17 | | 0.029 | | 0.033 | | 0.032 | | 0.04 |
| | | (0.123) | | (0.123) | | (0.122) | | (0.122) | | (0.072) | | (0.073) | | (0.072) | | (0.072) |
| Free food | -0.330*** | -0.403*** | -0.310*** | -0.370*** | -0.404*** | -0.483*** | -0.386*** | -0.451*** | -0.031 | -0.039 | -0.036 | -0.044 | -0.048 | -0.052 | -0.053 | -0.057 |
| | (0.083) | (0.095) | (0.082) | (0.093) | (0.085) | (0.098) | (0.084) | (0.096) | (0.042) | (0.045) | (0.042) | (0.046) | (0.041) | (0.045) | (0.042) | (0.046) |
| Free food*NDVI deviations | | -0.161 | | -0.123 | | -0.18 | | -0.143 | | -0.007 | | -0.004 | | 0 | | 0.001 |
| | | (0.108) | | (0.105) | | (0.112) | | (0.109) | | (0.049) | | (0.049) | | (0.048) | | (0.048) |
| Constant | 1.488*** | 1.492*** | 1.454*** | 1.459*** | 1.496*** | 1.495*** | 1.462*** | 1.461*** | 0.572*** | 0.579*** | 0.569*** | 0.576*** | 0.570*** | 0.575*** | 0.571*** | 0.576*** |
| | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.132) | (0.070) | (0.071) | (0.071) | (0.072) | (0.069) | (0.070) | (0.070) | (0.070) |
| Vsigma | | | | | | | | | | | | | | | | |
| Land (Ha) (IHS) | -0.287** | -0.288** | -0.251** | -0.251** | -0.292** | -0.293** | -0.253** | -0.255** | -1.323 | -1.319 | -0.885 | -0.9 | -1.454 | -1.496 | -1.692 | -1.737 |
| | (0.116) | (0.116) | (0.112) | (0.112) | (0.118) | (0.118) | (0.113) | (0.113) | (1.597) | (1.558) | (1.019) | (1.015) | (2.653) | (2.721) | (2.675) | (2.751) |
| Labour (IHS) | -0.111*** | -0.112*** | -0.098*** | -0.099*** | -0.115*** | -0.116*** | -0.100*** | -0.101*** | -0.013 | -0.013 | -0.044 | -0.043 | -0.041 | -0.038 | -0.019 | -0.017 |
| | (0.029) | (0.029) | (0.027) | (0.027) | (0.031) | (0.031) | (0.028) | (0.028) | (0.206) | (0.201) | (0.161) | (0.160) | (0.270) | (0.272) | (0.258) | (0.261) |
| Constant | 0.622*** | 0.632*** | 0.508*** | 0.516*** | 0.568*** | 0.579*** | 0.437*** | 0.445*** | -0.957 | -0.94 | -0.801 | -0.793 | -1.091 | -1.097 | -1.053 | -1.058 |
| | (0.140) | (0.140) | (0.128) | (0.128) | (0.150) | (0.150) | (0.137) | (0.137) | (0.843) | (0.825) | (0.657) | (0.652) | (1.031) | (1.044) | (1.005) | (1.016) |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

# Table S4: Profits full

| Frontier | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.011 | 0.012 | 0.013 | 0.013 | -0.463*** | -0.462*** | -0.466*** | -0.465*** | 0.071 | 0.069 | 0.079 | 0.08 | -0.052 | -0.104 |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.067) | (0.067) | (0.065) | (0.065) | (0.061) | (0.060) | (0.061) | (0.061) | (0.173) | (0.173) |
| Seed (IHS) | -0.007 | -0.007 | 0.01 | 0.01 | -0.014 | -0.011 | 0.033 | 0.036 | -0.064* | -0.064* | -0.073* | -0.072* | -0.146 | -0.21 |
| | (0.014) | (0.014) | (0.014) | (0.014) | (0.088) | (0.088) | (0.088) | (0.089) | (0.037) | (0.037) | (0.037) | (0.037) | (0.220) | (0.218) |
| Fertilizer (IHS) | 0.049*** | 0.048*** | 0.031** | 0.030** | 0.055 | 0.055 | 0.056 | 0.056 | -0.006 | -0.011 | -0.018 | -0.022 | 0.109 | 0.21 |
| | (0.015) | (0.015) | (0.015) | (0.015) | (0.094) | (0.094) | (0.092) | (0.092) | (0.031) | (0.031) | (0.031) | (0.031) | (0.175) | (0.179) |
| Land (Ha) (IHS) | 0.697*** | 0.698*** | 0.635*** | 0.636*** | 1.291*** | 1.293*** | 1.167*** | 1.167*** | 0.244 | 0.258 | 0.234 | 0.238 | 0.349 | 0.498 |
| | (0.048) | (0.048) | (0.049) | (0.049) | (0.230) | (0.229) | (0.237) | (0.236) | (0.172) | (0.171) | (0.169) | (0.170) | (0.545) | (0.552) |
| Year 2013 | 0.367*** | 0.362*** | -0.018 | -0.024 | 0.319*** | 0.314*** | -0.109 | -0.116 | 0.568*** | 0.546*** | 0.405* | 0.364 | 0.584*** | 0.33 |
| | (0.070) | (0.070) | (0.118) | (0.119) | (0.072) | (0.072) | (0.118) | (0.118) | (0.120) | (0.120) | (0.235) | (0.236) | (0.124) | (0.238) |
| Year 2015 | 1.234*** | 1.233*** | 1.088*** | 1.087*** | 1.234*** | 1.233*** | 1.133*** | 1.132*** | 1.373*** | 1.376*** | 0.828** | 0.892** | 1.410*** | 0.851** |
| | (0.070) | (0.070) | (0.176) | (0.176) | (0.070) | (0.070) | (0.178) | (0.178) | (0.112) | (0.113) | (0.401) | (0.404) | (0.115) | (0.401) |
| Price Sorghum | | | -0.006 | 0.012 | | | -0.046 | -0.03 | | | -0.107 | -0.071 | | -0.067 |
| | | | (0.133) | (0.133) | | | (0.134) | (0.134) | | | (0.294) | (0.292) | | (0.293) |
| Price Teff | | | -0.142 | -0.144 | | | -0.183** | -0.184** | | | -0.133 | -0.128 | | -0.157 |
| | | | (0.092) | (0.092) | | | (0.085) | (0.084) | | | (0.219) | (0.218) | | (0.221) |
| Price Wheat | | | -0.373*** | -0.371*** | | | -0.265* | -0.264* | | | -0.461 | -0.427 | | -0.443 |
| | | | (0.141) | (0.141) | | | (0.137) | (0.137) | | | (0.351) | (0.351) | | (0.348) |
| Price Sesame | | | 0.445*** | 0.444*** | | | 0.520*** | 0.519*** | | | 0.359 | 0.409 | | 0.451 |
| | | | (0.147) | (0.147) | | | (0.143) | (0.143) | | | (0.319) | (0.319) | | (0.321) |
| Price Lentils | | | 0.411** | 0.416*** | | | 0.363** | 0.366** | | | 0.919** | 0.848** | | 0.865** |
| | | | (0.160) | (0.160) | | | (0.166) | (0.166) | | | (0.394) | (0.400) | | (0.388) |
| Price Chat | | | -0.100** | -0.104** | | | -0.109** | -0.112** | | | 0.138 | 0.13 | | 0.145 |
| | | | (0.044) | (0.044) | | | (0.044) | (0.044) | | | (0.101) | (0.101) | | (0.101) |
| Price Coffee | | | 0.049 | 0.05 | | | 0.022 | 0.022 | | | 0.07 | 0.066 | | 0.052 |
| | | | (0.069) | (0.069) | | | (0.068) | (0.068) | | | (0.155) | (0.155) | | (0.155) |
| Price large ruminants | | | 0.170*** | 0.170*** | | | 0.173*** | 0.173*** | | | 0.136** | 0.130** | | 0.117* |
| | | | (0.029) | (0.029) | | | (0.029) | (0.029) | | | (0.061) | (0.061) | | (0.062) |
| Price small ruminants | | | 0.154 | 0.155 | | | 0.15 | 0.152 | | | 0.054 | 0.058 | | 0.061 |
| | | | (0.096) | (0.096) | | | (0.099) | (0.099) | | | (0.139) | (0.139) | | (0.138) |
| Price poultry | | | 0.154 | 0.154 | | | 0.142 | 0.143 | | | -0.049 | -0.058 | | -0.054 |
| | | | (0.096) | (0.095) | | | (0.094) | (0.094) | | | (0.163) | (0.163) | | (0.164) |
| Price Milk | | | -0.124** | -0.126** | | | -0.128** | -0.129** | | | -0.12 | -0.122 | | -0.096 |
| | | | (0.054) | (0.054) | | | (0.051) | (0.051) | | | (0.094) | (0.094) | | (0.095) |
| Labour*labour | | | | | 0.065*** | 0.065*** | 0.065*** | 0.065*** | | | | | 0.008 | 0.013 |
| | | | | | (0.011) | (0.011) | (0.011) | (0.011) | | | | | (0.022) | (0.022) |
| Seed*Seed | | | | | 0.014 | 0.014 | 0.012 | 0.012 | | | | | -0.029 | -0.032 |
| | | | | | (0.010) | (0.010) | (0.010) | (0.010) | | | | | (0.024) | (0.024) |
| Fert*Fert | | | | | 0.002 | 0.002 | -0.004 | -0.004 | | | | | -0.014 | -0.004 |
| | | | | | (0.010) | (0.010) | (0.008) | (0.008) | | | | | (0.016) | (0.016) |
| Land*Land | | | | | -0.112 | -0.115* | -0.116 | -0.119* | | | | | -0.13 | -0.212 |
| | | | | | (0.068) | (0.068) | (0.071) | (0.071) | | | | | (0.188) | (0.192) |
| Land*Labour | | | | | -0.066 | -0.065 | -0.054 | -0.052 | | | | | 0.049 | 0.065 |
| | | | | | (0.049) | (0.049) | (0.051) | (0.051) | | | | | (0.089) | (0.094) |
| Land*Seed | | | | | 0.027 | 0.027 | 0.019 | 0.019 | | | | | 0.003 | -0.026 |
| | | | | | (0.025) | (0.025) | (0.026) | (0.026) | | | | | (0.065) | (0.064) |
| Land*Fertilizer | | | | | -0.049** | -0.049** | -0.039* | -0.039* | | | | | -0.043 | -0.015 |
| | | | | | (0.023) | (0.023) | (0.023) | (0.023) | | | | | (0.046) | (0.046) |
| Labour*Seed | | | | | -0.017 | -0.017 | -0.018 | -0.018 | | | | | 0.033 | 0.052 |
| | | | | | (0.016) | (0.016) | (0.016) | (0.016) | | | | | (0.038) | (0.038) |
| Labour*Fert | | | | | 0.002 | 0.002 | 0.004 | 0.004 | | | | | 0.002 | -0.03 |
| | | | | | (0.016) | (0.016) | (0.016) | (0.016) | | | | | (0.031) | (0.031) |
| Seed*Fert | | | | | 0.008 | 0.008 | 0.006 | 0.006 | | | | | 0.001 | -0.001 |
| | | | | | (0.006) | (0.006) | (0.006) | (0.006) | | | | | (0.013) | (0.013) |
| Constant | 7.638*** | 7.631*** | 4.522*** | 4.494*** | 8.152*** | 8.143*** | 5.118*** | 5.086*** | | | | | | |
| | (0.163) | (0.163) | (0.491) | (0.491) | (0.182) | (0.182) | (0.503) | (0.503) | | | | | | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| Usigma | | | | | | | | | | | | | | |
| Agriculture asset index | -0.033* | -0.032* | -0.035* | -0.034* | -0.029* | -0.029 | -0.031* | -0.030* | 0.018 | 0.018 | 0.019* | 0.019* | 0.019* | 0.020* |
| | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Irrigation | 0.103* | 0.098 | 0.105* | 0.1 | 0.085 | 0.081 | 0.087 | 0.082 | -0.015 | -0.019 | -0.013 | -0.017 | -0.019 | -0.019 |
| | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.041) | (0.041) | (0.041) | (0.041) | (0.041) | (0.041) |
| Household Size | -0.041*** | -0.040*** | -0.043*** | -0.042*** | -0.038*** | -0.037*** | -0.040*** | -0.039*** | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Female-headed household (=1 if head is female) | 0.059 | 0.061 | 0.058 | 0.061 | 0.053 | 0.055 | 0.052 | 0.055 | -0.037 | -0.037 | -0.035 | -0.035 | -0.036 | -0.035 |
| | (0.047) | (0.047) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) | (0.035) |
| Average education | 0.070*** | 0.070*** | 0.070*** | 0.071*** | 0.071*** | 0.071*** | 0.071*** | 0.072*** | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.004 |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Time to city (IHS) | -0.044 | -0.041 | -0.04 | -0.037 | -0.044 | -0.041 | -0.039 | -0.036 | -0.035 | -0.034 | -0.035 | -0.034 | -0.032 | -0.032 |
| | (0.033) | (0.033) | (0.033) | (0.034) | (0.033) | (0.033) | (0.033) | (0.034) | (0.023) | (0.023) | (0.023) | (0.023) | (0.024) | (0.023) |
| NDVI deviations (IHS) | -0.119*** | -0.104*** | -0.119*** | -0.103*** | -0.120*** | -0.105*** | -0.120*** | -0.105*** | -0.078*** | -0.068*** | -0.080*** | -0.070*** | -0.070*** | -0.072*** |
| | (0.028) | (0.031) | (0.029) | (0.031) | (0.028) | (0.031) | (0.029) | (0.032) | (0.017) | (0.019) | (0.017) | (0.019) | (0.019) | (0.019) |
| PSNP labour | -0.110* | -0.152** | -0.111* | -0.154** | -0.115* | -0.159** | -0.115* | -0.161** | -0.008 | -0.032 | -0.009 | -0.033 | -0.031 | -0.031 |
| | (0.064) | (0.072) | (0.064) | (0.072) | (0.064) | (0.072) | (0.064) | (0.072) | (0.041) | (0.043) | (0.041) | (0.043) | (0.043) | (0.044) |
| PSNP cash | -0.415*** | -0.347*** | -0.420*** | -0.346*** | -0.422*** | -0.352*** | -0.427*** | -0.351*** | -0.164*** | -0.140** | -0.169*** | -0.144** | -0.141** | -0.145** |
| | (0.090) | (0.096) | (0.091) | (0.096) | (0.091) | (0.097) | (0.091) | (0.096) | (0.059) | (0.064) | (0.059) | (0.063) | (0.064) | (0.063) |
| Free food | -0.431*** | -0.499*** | -0.464*** | -0.538*** | -0.417*** | -0.482*** | -0.451*** | -0.522*** | -0.138*** | -0.174*** | -0.141*** | -0.175*** | -0.172*** | -0.175*** |
| | (0.076) | (0.086) | (0.076) | (0.087) | (0.076) | (0.086) | (0.076) | (0.087) | (0.041) | (0.044) | (0.041) | (0.044) | (0.044) | (0.044) |
| PSNP labour*NDVI deviations | | -0.08 | | -0.078 | | -0.088 | | -0.087 | | -0.058 | | -0.057 | -0.059 | -0.058 |
| | | (0.094) | | (0.095) | | (0.094) | | (0.095) | | (0.052) | | (0.052) | (0.052) | (0.052) |
| PSNP cash*NDVI deviations | | 0.228** | | 0.253** | | 0.233** | | 0.257** | | 0.073 | | 0.073 | 0.074 | 0.075 |
| | | (0.111) | | (0.110) | | (0.111) | | (0.111) | | (0.070) | | (0.070) | (0.070) | (0.070) |
| Free food*NDVI deviations | | -0.186* | | -0.206** | | -0.177* | | -0.195** | | -0.079 | | -0.072 | -0.076 | -0.071 |
| | | (0.096) | | (0.098) | | (0.095) | | (0.097) | | (0.050) | | (0.049) | (0.050) | (0.050) |
| Constant | 3.855*** | 3.848*** | 3.857*** | 3.849*** | 3.841*** | 3.835*** | 3.841*** | 3.833*** | 1.812*** | 1.812*** | 1.805*** | 1.805*** | 1.806*** | 1.800*** |
| | (0.105) | (0.105) | (0.106) | (0.106) | (0.105) | (0.105) | (0.106) | (0.106) | (0.074) | (0.074) | (0.074) | (0.074) | (0.075) | (0.074) |
| Vsigma | | | | | | | | | | | | | | |
| Land (Ha) (IHS) | -0.385** | -0.386** | -0.396** | -0.397** | -0.325* | -0.326* | -0.313* | -0.314* | -0.563 | -0.27 | -0.477 | -0.673 | -0.932 | -8.181 |
| | (0.181) | (0.181) | (0.190) | (0.190) | (0.169) | (0.169) | (0.179) | (0.178) | (1.231) | (0.496) | (47.258) | (9.323) | (0.888) | (19.748) |
| Labour (IHS) | -0.013 | -0.013 | -0.021 | -0.022 | -0.022 | -0.022 | -0.039 | -0.039 | 0.005 | -0.098 | -0.357 | 0.028 | -0.269 | 0.194 |
| | (0.043) | (0.043) | (0.046) | (0.046) | (0.043) | (0.043) | (0.046) | (0.046) | (54.737) | (22.731) | (16.016) | (1141.346) | (0.443) | (60.971) |
| Constant | 0.085 | 0.093 | 0.057 | 0.062 | 0.048 | 0.056 | 0.036 | 0.042 | -5.206 | -5.33 | -5.745 | -7.523 | -5.266 | -5.916 |
| | (0.209) | (0.208) | (0.220) | (0.219) | (0.209) | (0.207) | (0.215) | (0.214) | (424.143) | (548.826) | (212.684) | (128.282) | (946.960) | (1038.541) |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

## Table S5: Farm income - Full CHIRPS

| **Frontier** | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.278*** | 0.279*** | -0.179*** | -0.172*** | 0.217*** | 0.216*** | 0.157*** | 0.159*** |
| | (0.014) | (0.014) | (0.040) | (0.040) | (0.014) | (0.014) | (0.054) | (0.053) |
| Seed (IHS) | 0.001 | 0.001 | -0.015 | -0.013 | 0.001 | 0.002 | 0.032 | 0.033 |
| | (0.006) | (0.006) | (0.044) | (0.044) | (0.007) | (0.007) | (0.044) | (0.044) |
| Fertilizer (IHS) | 0.073*** | 0.072*** | 0.227*** | 0.223*** | 0.043*** | 0.041*** | 0.138*** | 0.133*** |
| | (0.006) | (0.006) | (0.040) | (0.040) | (0.006) | (0.006) | (0.036) | (0.036) |
| Land (Ha) (IHS) | 0.635*** | 0.638*** | 1.457*** | 1.460*** | 0.322*** | 0.326*** | 0.722*** | 0.716*** |
| | (0.023) | (0.023) | (0.120) | (0.120) | (0.033) | (0.033) | (0.127) | (0.127) |
| Year 2013 | 0.292*** | 0.291*** | 0.267*** | 0.267*** | 0.254*** | 0.251*** | 0.255*** | 0.252*** |
| | (0.029) | (0.029) | (0.030) | (0.030) | (0.026) | (0.026) | (0.027) | (0.027) |
| Year 2015 | 0.409*** | 0.415*** | 0.412*** | 0.417*** | 0.384*** | 0.390*** | 0.384*** | 0.389*** |
| | (0.029) | (0.029) | (0.029) | (0.029) | (0.024) | (0.024) | (0.024) | (0.024) |
| Labour*labour | | | 0.051*** | 0.051*** | | | 0.007 | 0.007 |
| | | | (0.005) | (0.005) | | | (0.005) | (0.005) |
| Seed*Seed | | | 0.018*** | 0.017*** | | | 0.010** | 0.010** |
| | | | (0.004) | (0.004) | | | (0.004) | (0.004) |
| Fert*Fert | | | 0.004 | 0.004 | | | 0 | 0 |
| | | | (0.003) | (0.003) | | | (0.003) | (0.003) |
| Land*Land | | | -0.230*** | -0.233*** | | | -0.191*** | -0.190*** |
| | | | (0.030) | (0.030) | | | (0.037) | (0.037) |
| Land*Labour | | | -0.048** | -0.047** | | | 0.014 | 0.014 |
| | | | (0.023) | (0.023) | | | (0.020) | (0.020) |
| Land*Seed | | | 0.027** | 0.028** | | | 0.01 | 0.011 |
| | | | (0.011) | (0.011) | | | (0.011) | (0.011) |
| Land*Fertilizer | | | -0.014 | -0.014 | | | -0.007 | -0.008 |
| | | | (0.009) | (0.009) | | | (0.008) | (0.008) |
| Labour*Seed | | | -0.016** | -0.016** | | | -0.014* | -0.014* |
| | | | (0.008) | (0.008) | | | (0.007) | (0.007) |
| Labour*Fert | | | -0.026*** | -0.025*** | | | -0.013** | -0.012** |
| | | | (0.007) | (0.007) | | | (0.006) | (0.006) |
| Seed*Fert | | | -0.001 | -0.001 | | | -0.002 | -0.002 |
| | | | (0.002) | (0.002) | | | (0.002) | (0.002) |
| Constant | 5.988*** | 5.980*** | 6.673*** | 6.650*** | | | | |
| | (0.095) | (0.094) | (0.120) | (0.121) | | | | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | | | | |
| **Usigma** | | | | | | | | |
| Agriculture asset index | -0.396*** | -0.399*** | -0.416*** | -0.419*** | -0.054*** | -0.053*** | -0.051*** | -0.051*** |
| | (0.068) | (0.070) | (0.060) | (0.062) | (0.012) | (0.013) | (0.012) | (0.013) |
| Irrigation | -1.039*** | -1.064*** | -1.151*** | -1.167*** | -0.320*** | -0.325*** | -0.316*** | -0.320*** |
| | (0.121) | (0.120) | (0.121) | (0.120) | (0.048) | (0.048) | (0.048) | (0.048) |
| Household Size | -0.086*** | -0.085*** | -0.075*** | -0.074*** | 0.001 | 0.001 | 0.002 | 0.002 |
| | (0.023) | (0.023) | (0.022) | (0.022) | (0.007) | (0.007) | (0.007) | (0.007) |
| Female-headed household (=1 if head is female) | 0.443*** | 0.450*** | 0.390*** | 0.395*** | 0.014 | 0.014 | 0.012 | 0.012 |
| | (0.085) | (0.086) | (0.085) | (0.086) | (0.044) | (0.044) | (0.044) | (0.044) |
| Average education | 0.034* | 0.033* | 0.033* | 0.031 | 0.013* | 0.012 | 0.011 | 0.011 |
| | (0.020) | (0.020) | (0.019) | (0.019) | (0.008) | (0.008) | (0.008) | (0.008) |
| Time to city (IHS) | 0.312*** | 0.323*** | 0.351*** | 0.362*** | 0.011 | 0.01 | 0.008 | 0.008 |
| | (0.074) | (0.075) | (0.073) | (0.074) | (0.028) | (0.029) | (0.028) | (0.029) |
| CHIRPS deviations (IHS) | -0.145*** | -0.068 | -0.166*** | -0.094* | -0.030* | -0.008 | -0.030* | -0.009 |
| | (0.049) | (0.054) | (0.049) | (0.054) | (0.017) | (0.019) | (0.017) | (0.019) |
| PSNP labour | 0.416*** | 0.273** | 0.393*** | 0.233* | 0.122*** | 0.087* | 0.120*** | 0.086* |
| | (0.113) | (0.125) | (0.115) | (0.130) | (0.043) | (0.046) | (0.043) | (0.046) |
| PSNP cash | -0.117 | -0.199 | -0.153 | -0.193 | -0.074 | -0.146* | -0.089 | -0.147** |
| | (0.141) | (0.174) | (0.146) | (0.186) | (0.068) | (0.075) | (0.068) | (0.075) |
| Free food | -0.058 | -0.292* | 0.001 | -0.188 | 0.109** | 0.034 | 0.116** | 0.045 |
| | (0.145) | (0.158) | (0.141) | (0.150) | (0.047) | (0.060) | (0.047) | (0.059) |
| PSNP labour*CHIRPS deviations | | -0.264** | | -0.296** | | -0.076* | | -0.074* |
| | | (0.126) | | (0.131) | | (0.042) | | (0.042) |
| PSNP cash*CHIRPS deviations | | -0.127 | | -0.056 | | -0.115 | | -0.095 |
| | | (0.170) | | (0.184) | | (0.072) | | (0.072) |
| Free food*CHIRPS deviations | | -0.363*** | | -0.299** | | -0.100* | | -0.095* |
| | | (0.139) | | (0.136) | | (0.056) | | (0.056) |
| Constant | -0.732*** | -0.743*** | -0.807*** | -0.824*** | -0.036 | -0.032 | -0.04 | -0.035 |
| | (0.248) | (0.252) | (0.239) | (0.244) | (0.085) | (0.085) | (0.085) | (0.085) |
| **Vsigma** | | | | | | | | |
| Land (Ha) (IHS) | -0.134* | -0.135* | -0.131** | -0.131** | -0.514*** | -0.535*** | -0.522*** | -0.539*** |
| | (0.070) | (0.070) | (0.066) | (0.066) | (0.098) | (0.098) | (0.101) | (0.100) |
| Labour (IHS) | -0.256*** | -0.258*** | -0.212*** | -0.215*** | -0.175*** | -0.175*** | -0.179*** | -0.179*** |
| | (0.019) | (0.019) | (0.021) | (0.021) | (0.019) | (0.018) | (0.019) | (0.019) |
| Constant | 1.277*** | 1.288*** | 1.004*** | 1.025*** | 0.481*** | 0.501*** | 0.490*** | 0.509*** |
| | (0.090) | (0.089) | (0.102) | (0.102) | (0.075) | (0.073) | (0.076) | (0.074) |
| Number of observations | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

# Table S6: Sales full CHIRPS

| Frontier | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.100*** | 0.100*** | -0.453*** | -0.455*** | 0.099*** | 0.099*** | -0.454*** | -0.456*** | 0.138*** | 0.138*** | -0.191** | -0.196*** | 0.138*** | 0.137*** | -0.200*** | |
| | (0.017) | (0.017) | (0.045) | (0.045) | (0.017) | (0.017) | (0.043) | (0.043) | (0.023) | (0.023) | (0.074) | (0.074) | (0.023) | (0.023) | (0.071) | |
| Seed (IHS) | 0.008 | 0.009 | 0.05 | 0.05 | 0.019** | 0.019** | 0.069 | 0.069 | 0.021 | 0.021 | 0.158** | 0.159** | 0.024* | 0.024* | 0.135* | |
| | (0.009) | (0.009) | (0.059) | (0.059) | (0.009) | (0.009) | (0.058) | (0.058) | (0.013) | (0.013) | (0.080) | (0.080) | (0.013) | (0.013) | (0.078) | |
| Fertilizer (IHS) | 0.036*** | 0.036*** | 0.113* | 0.112* | 0.023** | 0.023** | 0.108* | 0.108* | 0.018* | 0.018* | 0.057 | 0.054 | 0.01 | 0.01 | 0.09 | |
| | (0.009) | (0.009) | (0.059) | (0.059) | (0.009) | (0.009) | (0.057) | (0.057) | (0.010) | (0.010) | (0.063) | (0.063) | (0.011) | (0.011) | (0.061) | |
| Land (Ha) (IHS) | 0.618*** | 0.618*** | 1.365*** | 1.368*** | 0.561*** | 0.561*** | 1.200*** | 1.203*** | 0.406*** | 0.407*** | 0.572*** | 0.583*** | 0.406*** | 0.406*** | 0.577*** | |
| | (0.032) | (0.032) | (0.170) | (0.170) | (0.032) | (0.032) | (0.168) | (0.168) | (0.060) | (0.060) | (0.218) | (0.219) | (0.059) | (0.059) | (0.211) | |
| Year 2013 | 0.291*** | 0.291*** | 0.258*** | 0.258*** | 0.029 | 0.028 | -0.035 | -0.036 | 0.369*** | 0.368*** | 0.379*** | 0.377*** | 0.211** | 0.207** | 0.211** | |
| | (0.043) | (0.043) | (0.044) | (0.044) | (0.075) | (0.075) | (0.076) | (0.076) | (0.044) | (0.044) | (0.046) | (0.046) | (0.084) | (0.084) | (0.084) | |
| Year 2015 | 0.918*** | 0.918*** | 0.907*** | 0.906*** | 0.666*** | 0.666*** | 0.637*** | 0.636*** | 0.826*** | 0.827*** | 0.833*** | 0.833*** | 0.343** | 0.340** | 0.321** | |
| | (0.043) | (0.043) | (0.043) | (0.043) | (0.121) | (0.121) | (0.121) | (0.121) | (0.041) | (0.041) | (0.042) | (0.042) | (0.144) | (0.144) | (0.143) | |
| Labour*labour | | | 0.073*** | 0.073*** | | | 0.072*** | 0.072*** | | | 0.032*** | 0.033*** | | | 0.032*** | |
| | | | (0.007) | (0.007) | | | (0.007) | (0.007) | | | (0.009) | (0.009) | | | (0.008) | |
| Seed*Seed | | | 0.010* | 0.010* | | | 0.009 | 0.009 | | | -0.007 | -0.007 | | | -0.007 | |
| | | | (0.006) | (0.006) | | | (0.006) | (0.006) | | | (0.008) | (0.008) | | | (0.008) | |
| Fert*Fert | | | 0.002 | 0.002 | | | -0.002 | -0.002 | | | -0.003 | -0.003 | | | -0.006 | |
| | | | (0.005) | (0.005) | | | (0.005) | (0.005) | | | (0.005) | (0.005) | | | (0.005) | |
| Land*Land | | | -0.087* | -0.085* | | | -0.094** | -0.093** | | | -0.174*** | -0.172** | | | -0.226*** | |
| | | | (0.044) | (0.044) | | | (0.043) | (0.043) | | | (0.067) | (0.067) | | | (0.065) | |
| Land*Labour | | | -0.100*** | -0.101*** | | | -0.079** | -0.080** | | | 0.047 | 0.045 | | | 0.064* | |
| | | | (0.034) | (0.034) | | | (0.033) | (0.033) | | | (0.036) | (0.036) | | | (0.035) | |
| Land*Seed | | | 0.039** | 0.039** | | | 0.034** | 0.033** | | | 0.007 | 0.008 | | | -0.011 | |
| | | | (0.016) | (0.016) | | | (0.016) | (0.016) | | | (0.021) | (0.021) | | | (0.020) | |
| Land*Fertilizer | | | -0.038*** | -0.038*** | | | -0.029** | -0.029** | | | -0.021 | -0.022 | | | 0.009 | |
| | | | (0.014) | (0.014) | | | (0.014) | (0.014) | | | (0.014) | (0.014) | | | (0.014) | |
| Labour*Seed | | | -0.024** | -0.024** | | | -0.022** | -0.022** | | | -0.021 | -0.021 | | | -0.012 | |
| | | | (0.010) | (0.010) | | | (0.010) | (0.010) | | | (0.013) | (0.013) | | | (0.013) | |
| Labour*Fert | | | -0.009 | -0.009 | | | -0.009 | -0.009 | | | -0.001 | 0 | | | -0.009 | |
| | | | (0.010) | (0.010) | | | (0.010) | (0.010) | | | (0.011) | (0.011) | | | (0.010) | |
| Seed*Fert | | | 0.005 | 0.005 | | | 0.003 | 0.003 | | | 0.006 | 0.006 | | | 0.003 | |
| | | | (0.004) | (0.004) | | | (0.003) | (0.003) | | | (0.004) | (0.004) | | | (0.004) | |
| Price Sorghum | | | | | 0.011 | 0.009 | 0.013 | 0.009 | | | | | 0.152 | 0.148 | 0.185* | |
| | | | | | (0.093) | (0.093) | (0.093) | (0.094) | | | | | (0.107) | (0.108) | (0.108) | |
| Price Teff | | | | | -0.186*** | -0.186*** | -0.209*** | -0.210*** | | | | | 0.041 | 0.042 | 0.026 | |
| | | | | | (0.056) | (0.056) | (0.057) | (0.057) | | | | | (0.074) | (0.074) | (0.074) | |
| Price Wheat | | | | | -0.285*** | -0.287*** | -0.234** | -0.237** | | | | | -0.387*** | -0.391*** | -0.383*** | |
| | | | | | (0.100) | (0.100) | (0.099) | (0.099) | | | | | (0.125) | (0.125) | (0.124) | |
| Price Sesame | | | | | 0.343*** | 0.345*** | 0.387*** | 0.390*** | | | | | 0.301** | 0.305*** | 0.332*** | |
| | | | | | (0.100) | (0.100) | (0.100) | (0.100) | | | | | (0.117) | (0.117) | (0.117) | |
| Price Lentils | | | | | 0.374*** | 0.373*** | 0.354*** | 0.351*** | | | | | 0.677*** | 0.674*** | 0.690*** | |
| | | | | | (0.122) | (0.122) | (0.124) | (0.123) | | | | | (0.154) | (0.154) | (0.152) | |
| Price Chat | | | | | -0.059** | -0.059** | -0.046 | -0.045 | | | | | -0.038 | -0.037 | -0.025 | |
| | | | | | (0.028) | (0.028) | (0.028) | (0.028) | | | | | (0.035) | (0.035) | (0.035) | |
| Price Coffee | | | | | 0.011 | 0.01 | -0.027 | -0.027 | | | | | -0.074 | -0.075 | -0.089* | |
| | | | | | (0.043) | (0.043) | (0.043) | (0.043) | | | | | (0.051) | (0.051) | (0.051) | |
| Price large ruminants | | | | | 0.122*** | 0.122*** | 0.120*** | 0.120*** | | | | | 0.102*** | 0.103*** | 0.102*** | |
| | | | | | (0.019) | (0.019) | (0.019) | (0.019) | | | | | (0.021) | (0.021) | (0.021) | |
| Price small ruminants | | | | | 0.142** | 0.142** | 0.151*** | 0.151*** | | | | | 0.048 | 0.047 | 0.063 | |
| | | | | | (0.056) | (0.056) | (0.055) | (0.055) | | | | | (0.048) | (0.048) | (0.049) | |
| Price poultry | | | | | 0.180*** | 0.180*** | 0.166** | 0.167** | | | | | -0.02 | -0.017 | -0.034 | |
| | | | | | (0.068) | (0.068) | (0.067) | (0.067) | | | | | (0.058) | (0.057) | (0.057) | |
| Price Milk | | | | | -0.023 | -0.023 | -0.014 | -0.014 | | | | | 0.078** | 0.078** | 0.085** | |
| | | | | | (0.030) | (0.030) | (0.029) | (0.029) | | | | | (0.035) | (0.035) | (0.034) | |
| Constant | 7.020*** | 7.023*** | 7.702*** | 7.709*** | 4.364*** | 4.369*** | 5.097*** | 5.106*** | | | | | | | | |
| | (0.116) | (0.116) | (0.123) | (0.124) | (0.304) | (0.304) | (0.301) | (0.301) | | | | | | | | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Usigma | | | | | | | | | | | | | | | | |
| Agriculture asset index | -0.198*** | -0.197*** | -0.192*** | -0.192*** | -0.203*** | -0.203*** | -0.197*** | -0.197*** | -0.045*** | -0.044*** | -0.043*** | -0.043*** | -0.046*** | -0.046*** | -0.045*** | |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.022) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | |
| Irrigation | -0.185** | -0.182** | -0.243*** | -0.237*** | -0.188** | -0.185** | -0.247*** | -0.241*** | -0.128*** | -0.125*** | -0.132*** | -0.128*** | -0.137*** | -0.132*** | -0.135*** | |
| | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.040) | (0.040) | (0.040) | (0.040) | (0.039) | (0.039) | (0.040) | |
| Household Size | -0.087*** | -0.087*** | -0.081*** | -0.081*** | -0.092*** | -0.092*** | -0.086*** | -0.086*** | -0.019*** | -0.019*** | -0.019*** | -0.019*** | -0.020*** | -0.020*** | -0.020*** | |
| | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | |
| Female-headed household (=1 if head is female) | 0.298*** | 0.298*** | 0.291*** | 0.291*** | 0.296*** | 0.296*** | 0.290*** | 0.289*** | 0.108*** | 0.108*** | 0.108*** | 0.108*** | 0.102*** | 0.102*** | 0.101*** | |
| | (0.056) | (0.056) | (0.056) | (0.056) | (0.056) | (0.056) | (0.056) | (0.056) | (0.035) | (0.035) | (0.036) | (0.036) | (0.035) | (0.035) | (0.035) | |
| Average education | 0.035*** | 0.035*** | 0.037*** | 0.037*** | 0.037*** | 0.037*** | 0.040*** | 0.040*** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | 0.015** | |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.007) | (0.007) | (0.007) | (0.007) | (0.006) | (0.006) | (0.007) | |
| Time to city (IHS) | 0.281*** | 0.278*** | 0.287*** | 0.284*** | 0.296*** | 0.294*** | 0.303*** | 0.301*** | 0.131*** | 0.129*** | 0.131*** | 0.129*** | 0.138*** | 0.135*** | 0.135*** | |
| | (0.042) | (0.042) | (0.042) | (0.043) | (0.042) | (0.042) | (0.042) | (0.043) | (0.024) | (0.024) | (0.024) | (0.024) | (0.023) | (0.023) | (0.023) | |
| CHIRPS deviations (IHS) | -0.221*** | -0.219*** | -0.226*** | -0.227*** | -0.220*** | -0.222*** | -0.225*** | -0.230*** | -0.089*** | -0.086*** | -0.091*** | -0.088*** | -0.091*** | -0.091*** | -0.092*** | |
| | (0.029) | (0.032) | (0.029) | (0.032) | (0.029) | (0.032) | (0.029) | (0.032) | (0.014) | (0.016) | (0.015) | (0.016) | (0.014) | (0.016) | (0.016) | |
| PSNP labour | 0.120* | 0.124 | 0.105 | 0.103 | 0.112 | 0.122 | 0.097 | 0.101 | 0.059 | 0.048 | 0.058 | 0.044 | 0.054 | 0.052 | 0.049 | |
| | (0.072) | (0.079) | (0.073) | (0.079) | (0.073) | (0.078) | (0.073) | (0.079) | (0.040) | (0.043) | (0.040) | (0.043) | (0.039) | (0.043) | (0.043) | |
| PSNP cash | -0.008 | -0.069 | -0.03 | -0.072 | -0.015 | -0.055 | -0.037 | -0.06 | 0.013 | -0.018 | 0.008 | -0.021 | 0.01 | -0.022 | -0.025 | |
| | (0.105) | (0.121) | (0.105) | (0.121) | (0.105) | (0.120) | (0.105) | (0.120) | (0.056) | (0.066) | (0.056) | (0.067) | (0.055) | (0.066) | (0.066) | |
| Free food | -0.376*** | -0.358*** | -0.358*** | -0.321*** | -0.454*** | -0.434*** | -0.436*** | -0.398*** | -0.042 | -0.025 | -0.047 | -0.028 | -0.062 | -0.034 | -0.035 | |
| | (0.083) | (0.097) | (0.083) | (0.094) | (0.085) | (0.099) | (0.084) | (0.096) | (0.042) | (0.049) | (0.042) | (0.049) | (0.042) | (0.049) | (0.049) | |
| PSNP labour*CHIRPS deviations | | -0.002 | | -0.02 | | 0.015 | | -0.002 | | -0.03 | | -0.038 | | -0.011 | -0.015 | |
| | | (0.077) | | (0.077) | | (0.078) | | (0.078) | | (0.045) | | (0.045) | | (0.045) | (0.045) | |
| PSNP cash*CHIRPS deviations | | -0.11 | | -0.079 | | -0.072 | | -0.04 | | -0.053 | | -0.05 | | -0.054 | -0.048 | |
| | | (0.112) | | (0.113) | | (0.112) | | (0.112) | | (0.069) | | (0.069) | | (0.069) | (0.069) | |
| Free food*CHIRPS deviations | | 0.037 | | 0.078 | | 0.038 | | 0.078 | | 0.033 | | 0.038 | | 0.052 | 0.057 | |
| | | (0.089) | | (0.087) | | (0.091) | | (0.089) | | (0.047) | | (0.047) | | (0.046) | (0.047) | |
| Constant | 1.444*** | 1.448*** | 1.406*** | 1.410*** | 1.449*** | 1.450*** | 1.409*** | 1.411*** | 0.566*** | 0.570*** | 0.562*** | 0.566*** | 0.559*** | 0.562*** | 0.562*** | |
| | (0.130) | (0.130) | (0.130) | (0.130) | (0.130) | (0.131) | (0.130) | (0.131) | (0.072) | (0.072) | (0.073) | (0.073) | (0.071) | (0.071) | (0.071) | |
| Vsigma | | | | | | | | | | | | | | | | |
| Land (Ha) (IHS) | -0.296** | -0.296** | -0.260** | -0.260** | -0.302** | -0.302** | -0.266** | -0.265** | -1.383 | -1.387 | -1.297 | -1.301 | -1.457 | -1.45 | -1.859 | |
| | (0.116) | (0.116) | (0.113) | (0.113) | (0.118) | (0.118) | (0.113) | (0.113) | (1.204) | (1.200) | (1.022) | (1.020) | (1.906) | (1.915) | (2.253) | |
| Labour (IHS) | -0.110*** | -0.110*** | -0.098*** | -0.098*** | -0.114*** | -0.114*** | -0.099*** | -0.099*** | 0.009 | 0.011 | 0.003 | 0.005 | -0.005 | -0.004 | 0.013 | |
| | (0.029) | (0.029) | (0.026) | (0.026) | (0.031) | (0.031) | (0.028) | (0.028) | (0.165) | (0.166) | (0.143) | (0.145) | (0.227) | (0.232) | (0.231) | |
| Constant | 0.626*** | 0.625*** | 0.517*** | 0.514*** | 0.573*** | 0.572*** | 0.445*** | 0.443*** | -0.835 | -0.843 | -0.736 | -0.749 | -1.047 | -1.063 | -1.025 | |
| | (0.141) | (0.141) | (0.129) | (0.129) | (0.151) | (0.151) | (0.137) | (0.137) | (0.714) | (0.722) | (0.616) | (0.628) | (0.960) | (0.984) | (0.973) | |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | 8867 | |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

# Table S7: Profits full CHIRPS

| Frontier | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| Labour (IHS) | 0.011 | 0.013 | 0.014 | 0.015 | -0.466*** | -0.456*** | -0.469*** | -0.460*** | 0.083 |
| | (0.022) | (0.022) | (0.022) | (0.022) | (0.067) | (0.067) | (0.065) | (0.065) | (0.060) |
| Seed (IHS) | -0.007 | -0.007 | 0.011 | 0.01 | -0.009 | -0.004 | 0.037 | 0.042 | -0.067* |
| | (0.014) | (0.014) | (0.014) | (0.014) | (0.088) | (0.088) | (0.089) | (0.089) | (0.037) |
| Fertilizer (IHS) | 0.050*** | 0.047*** | 0.032** | 0.029** | 0.06 | 0.058 | 0.059 | 0.057 | -0.012 |
| | (0.015) | (0.015) | (0.015) | (0.015) | (0.094) | (0.094) | (0.092) | (0.092) | (0.031) |
| Land (Ha) (IHS) | 0.693*** | 0.697*** | 0.630*** | 0.635*** | 1.300*** | 1.288*** | 1.179*** | 1.162*** | 0.276 |
| | (0.048) | (0.048) | (0.049) | (0.049) | (0.232) | (0.229) | (0.238) | (0.236) | (0.170) |
| Year 2013 | 0.395*** | 0.390*** | 0.003 | 0.008 | 0.347*** | 0.342*** | -0.087 | -0.083 | 0.646*** |
| | (0.070) | (0.070) | (0.118) | (0.118) | (0.071) | (0.071) | (0.118) | (0.118) | (0.119) |
| Year 2015 | 1.221*** | 1.230*** | 1.076*** | 1.083*** | 1.223*** | 1.231*** | 1.123*** | 1.129*** | 1.403*** |
| | (0.070) | (0.071) | (0.176) | (0.176) | (0.070) | (0.070) | (0.178) | (0.178) | (0.115) |
| Price Sorghum | | | -0.013 | 0.005 | | | -0.054 | -0.036 | |
| | | | (0.133) | (0.132) | | | (0.134) | (0.134) | |
| Price Teff | | | -0.152* | -0.151* | | | -0.191** | -0.190** | |
| | | | (0.090) | (0.090) | | | (0.083) | (0.084) | |
| Price Wheat | | | -0.375*** | -0.359** | | | -0.270** | -0.254* | |
| | | | (0.141) | (0.141) | | | (0.137) | (0.137) | |
| Price Sesame | | | 0.458*** | 0.442*** | | | 0.533*** | 0.518*** | |
| | | | (0.147) | (0.147) | | | (0.143) | (0.143) | |
| Price Lentils | | | 0.416*** | 0.428*** | | | 0.368** | 0.378** | |
| | | | (0.160) | (0.160) | | | (0.165) | (0.165) | |
| Price Chat | | | -0.101** | -0.106** | | | -0.110** | -0.115*** | |
| | | | (0.044) | (0.044) | | | (0.044) | (0.044) | |
| Price Coffee | | | 0.048 | 0.052 | | | 0.021 | 0.025 | |
| | | | (0.069) | (0.069) | | | (0.068) | (0.068) | |
| Price large ruminants | | | 0.167*** | 0.167*** | | | 0.171*** | 0.170*** | |
| | | | (0.029) | (0.029) | | | (0.029) | (0.029) | |
| Price small ruminants | | | 0.154 | 0.154 | | | 0.151 | 0.152 | |
| | | | (0.096) | (0.096) | | | (0.098) | (0.098) | |
| Price poultry | | | 0.158* | 0.155 | | | 0.146 | 0.143 | |
| | | | (0.095) | (0.095) | | | (0.094) | (0.094) | |
| Price Milk | | | -0.124** | -0.123** | | | -0.128** | -0.126** | |
| | | | (0.054) | (0.053) | | | (0.051) | (0.051) | |
| Labour*labour | | | | | 0.066*** | 0.065*** | 0.066*** | 0.065*** | |
| | | | | | (0.011) | (0.011) | (0.011) | (0.011) | |
| Seed*Seed | | | | | 0.014 | 0.014 | 0.012 | 0.011 | |
| | | | | | (0.010) | (0.010) | (0.010) | (0.010) | |
| Fert*Fert | | | | | 0.002 | 0.002 | -0.004 | -0.004 | |
| | | | | | (0.010) | (0.010) | (0.008) | (0.008) | |
| Land*Land | | | | | -0.11 | -0.118* | -0.114 | -0.121* | |
| | | | | | (0.068) | (0.068) | (0.071) | (0.071) | |
| Land*Labour | | | | | -0.069 | -0.063 | -0.057 | -0.051 | |
| | | | | | (0.049) | (0.049) | (0.051) | (0.051) | |
| Land*Seed | | | | | 0.027 | 0.028 | 0.019 | 0.021 | |
| | | | | | (0.025) | (0.025) | (0.026) | (0.026) | |
| Land*Fertilizer | | | | | -0.047** | -0.048** | -0.038* | -0.039* | |
| | | | | | (0.023) | (0.023) | (0.023) | (0.023) | |
| Labour*Seed | | | | | -0.018 | -0.019 | -0.018 | -0.019 | |
| | | | | | (0.016) | (0.016) | (0.016) | (0.016) | |
| Labour*Fert | | | | | 0.001 | 0.001 | 0.003 | 0.003 | |
| | | | | | (0.016) | (0.016) | (0.016) | (0.016) | |
| Seed*Fert | | | | | 0.008 | 0.008 | 0.006 | 0.006 | |
| | | | | | (0.006) | (0.006) | (0.006) | (0.006) | |
| Constant | 7.611*** | 7.591*** | 4.498*** | 4.458*** | 8.123*** | 8.092*** | 5.088*** | 5.038*** | |
| | (0.163) | (0.163) | (0.491) | (0.490) | (0.181) | (0.181) | (0.503) | (0.503) | |
| Region dummies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Usigma | | | | | | | | | |
| Agriculture asset index | -0.031* | -0.031* | -0.033* | -0.033* | -0.027 | -0.027 | -0.029 | -0.029 | 0.019* |
| | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.018) | (0.011) |
| Irrigation | 0.109* | 0.085 | 0.111* | 0.086 | 0.091 | 0.068 | 0.092 | 0.069 | -0.026 |
| | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.062) | (0.041) |
| Household Size | -0.040*** | -0.039*** | -0.042*** | -0.041*** | -0.037*** | -0.036*** | -0.039*** | -0.038*** | 0.009 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.006) |
| Female-headed household (=1 if head is female) | 0.059 | 0.062 | 0.057 | 0.061 | 0.053 | 0.055 | 0.052 | 0.055 | -0.034 |
| | (0.048) | (0.047) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.048) | (0.035) |
| Average education | 0.070*** | 0.068*** | 0.070*** | 0.069*** | 0.071*** | 0.069*** | 0.071*** | 0.070*** | 0.002 |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.007) |
| Time to city (IHS) | -0.066** | -0.059* | -0.061* | -0.054 | -0.066** | -0.059* | -0.060* | -0.052 | -0.043* |
| | (0.033) | (0.033) | (0.033) | (0.033) | (0.033) | (0.033) | (0.033) | (0.033) | (0.023) |
| CHIRPS deviations (IHS) | 0.021 | 0.055** | 0.016 | 0.049* | 0.019 | 0.052** | 0.014 | 0.046* | 0.013 |
| | (0.023) | (0.025) | (0.023) | (0.026) | (0.023) | (0.025) | (0.023) | (0.026) | (0.016) |
| PSNP labour | -0.084 | -0.132* | -0.086 | -0.132* | -0.089 | -0.139** | -0.091 | -0.139** | -0.037 |
| | (0.064) | (0.069) | (0.065) | (0.069) | (0.064) | (0.069) | (0.065) | (0.069) | (0.043) |
| PSNP cash | -0.399*** | -0.346*** | -0.406*** | -0.344*** | -0.406*** | -0.348*** | -0.414*** | -0.347*** | -0.157** |
| | (0.090) | (0.102) | (0.091) | (0.102) | (0.091) | (0.102) | (0.091) | (0.102) | (0.068) |
| Free food | -0.380*** | -0.557*** | -0.416*** | -0.599*** | -0.367*** | -0.535*** | -0.404*** | -0.578*** | -0.213*** |
| | (0.076) | (0.087) | (0.077) | (0.088) | (0.076) | (0.086) | (0.077) | (0.087) | (0.047) |
| PSNP labour*CHIRPS deviations | | -0.078 | | -0.071 | | -0.086 | | -0.077 | -0.084** |
| | | (0.070) | | (0.070) | | (0.070) | | (0.070) | (0.040) |
| PSNP cash*CHIRPS deviations | | 0.113 | | 0.131 | | 0.123 | | 0.142 | 0.002 |
| | | (0.101) | | (0.101) | | (0.101) | | (0.101) | (0.063) |
| Free food*CHIRPS deviations | | -0.326*** | | -0.339*** | | -0.308*** | | -0.321*** | -0.150*** |
| | | (0.082) | | (0.084) | | (0.081) | | (0.082) | (0.045) |
| Constant | 3.899*** | 3.901*** | 3.899*** | 3.901*** | 3.886*** | 3.887*** | 3.884*** | 3.884*** | 1.840*** |
| | (0.104) | (0.104) | (0.105) | (0.105) | (0.104) | (0.104) | (0.105) | (0.105) | (0.075) |
| Vsigma | | | | | | | | | |
| Land (Ha) (IHS) | -0.378** | -0.380** | -0.388** | -0.389** | -0.320* | -0.321* | -0.307* | -0.309* | -0.447 |
| | (0.181) | (0.181) | (0.190) | (0.190) | (0.170) | (0.169) | (0.179) | (0.178) | (278.065) |
| Labour (IHS) | -0.013 | -0.015 | -0.023 | -0.024 | -0.022 | -0.024 | -0.04 | -0.041 | 0.135 |
| | (0.043) | (0.043) | (0.046) | (0.046) | (0.043) | (0.043) | (0.046) | (0.046) | (0.175) |
| Constant | 0.081 | 0.095 | 0.057 | 0.066 | 0.046 | 0.062 | 0.038 | 0.049 | -5.478 |
| | (0.210) | (0.208) | (0.220) | (0.219) | (0.210) | (0.207) | (0.215) | (0.214) | (267.322) |
| N | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 9309 | 8867 |

Notes: ***, **, * denote the statistical significance of the coefficient and the numbers in brackets denote the standard errors of the coefficients. For all estimates where fixed effects are not included, standard errors are robust standard errors.

## Table S8: Summary - NDVI

Farm Income

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| NDVI deviations (IHS) | -0.213*** | -0.144** | -0.214*** | -0.151** | -0.109*** | -0.087*** | -0.111*** | -0.088*** |
| | (0.053) | (0.059) | (0.053) | (0.059) | (0.019) | (0.021) | (0.019) | (0.021) |
| PSNP labour | 0.428*** | 0.313** | 0.408*** | 0.278** | 0.114*** | 0.073 | 0.112*** | 0.067 |
| | (0.113) | (0.122) | (0.115) | (0.125) | (0.043) | (0.044) | (0.043) | (0.044) |
| PSNP labour*NDVI deviations | | -0.248* | | -0.290* | | -0.107** | | -0.115** |
| | | (0.143) | | (0.149) | | (0.054) | | (0.053) |
| PSNP cash | -0.102 | -0.095 | -0.131 | -0.1 | -0.083 | -0.112 | -0.098 | -0.121* |
| | (0.142) | (0.160) | (0.146) | (0.165) | (0.068) | (0.070) | (0.068) | (0.071) |
| PSNP cash*NDVI deviations | | 0.026 | | 0.073 | | -0.071 | | -0.059 |
| | | (0.169) | | (0.177) | | (0.074) | | (0.076) |
| Free food | -0.07 | -0.253 | -0.004 | -0.145 | 0.087* | 0.05 | 0.095** | 0.058 |
| | (0.152) | (0.201) | (0.148) | (0.186) | (0.046) | (0.049) | (0.046) | (0.049) |
| Free food*NDVI deviations | | -0.353* | | -0.273 | | -0.055 | | -0.054 |
| | | (0.189) | | (0.179) | | (0.056) | | (0.057) |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Estimator | PC | PC | PC | PC | PDE | PDE | PDE | PDE |

Sales

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| NDVI deviations (IHS) | -0.127*** | -0.098*** | -0.127*** | -0.102*** | -0.088*** | -0.080*** | -0.089*** | -0.081*** |
| | (0.034) | (0.038) | (0.034) | (0.038) | (0.017) | (0.018) | (0.017) | (0.018) |
| PSNP labour | 0.150** | 0.081 | 0.137* | 0.062 | 0.065* | 0.032 | 0.065* | 0.029 |
| | (0.072) | (0.079) | (0.073) | (0.080) | (0.039) | (0.043) | (0.040) | (0.043) |
| PSNP labour*NDVI deviations | | -0.173* | | -0.194* | | -0.09 | | -0.098 |
| | | (0.099) | | (0.100) | | (0.059) | | (0.060) |
| PSNP cash | 0.054 | 0.095 | 0.032 | 0.078 | 0.031 | 0.045 | 0.027 | 0.041 |
| | (0.106) | (0.115) | (0.106) | (0.115) | (0.055) | (0.058) | (0.055) | (0.058) |
| PSNP cash*NDVI deviations | | 0.103 | | 0.117 | | 0.029 | | 0.033 |
| | | (0.123) | | (0.123) | | (0.072) | | (0.073) |
| Free food | -0.330*** | -0.403*** | -0.310*** | -0.370*** | -0.031 | -0.039 | -0.036 | -0.044 |
| | (0.083) | (0.095) | (0.082) | (0.093) | (0.042) | (0.045) | (0.042) | (0.046) |
| Free food*NDVI deviations | | -0.161 | | -0.123 | | -0.007 | | -0.004 |
| | | (0.108) | | (0.105) | | (0.049) | | (0.049) |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Estimator | PC | PC | PC | PC | PDE | PDE | PDE | PDE |

Profits

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| NDVI deviations (IHS) | -0.119*** | -0.104*** | -0.119*** | -0.103*** | -0.078*** | -0.068*** |
| | (0.028) | (0.031) | (0.029) | (0.031) | (0.017) | (0.019) |
| PSNP labour | -0.110* | -0.152** | -0.111* | -0.154** | -0.008 | -0.032 |
| | (0.064) | (0.072) | (0.064) | (0.072) | (0.041) | (0.043) |
| PSNP cash | -0.415*** | -0.347*** | -0.420*** | -0.346*** | -0.164*** | -0.140** |
| | (0.090) | (0.096) | (0.091) | (0.096) | (0.059) | (0.064) |
| Free food | -0.431*** | -0.499*** | -0.464*** | -0.538*** | -0.138*** | -0.174*** |
| | (0.076) | (0.086) | (0.076) | (0.087) | (0.041) | (0.044) |
| PSNP labour*NDVI deviations | | -0.08 | | -0.078 | | -0.058 |
| | | (0.094) | | (0.095) | | (0.052) |
| PSNP cash*NDVI deviations | | 0.228** | | 0.253** | | 0.073 |
| | | (0.111) | | (0.110) | | (0.070) |
| Free food*NDVI deviations | | -0.186* | | -0.206** | | -0.079 |
| | | (0.096) | | (0.098) | | (0.050) |
| Functional form | CD | CD | TLG | TLG | CD | CD |
| Estimator | PC | PC | PC | PC | PDE | PDE |

## Table S9: Summary - CHIRPS

Farm Income

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| CHIRPS deviations (IHS) | -0.145*** | -0.068 | -0.166*** | -0.094* | -0.030* | -0.008 | -0.030* | -0.009 |
| | (0.049) | (0.054) | (0.049) | (0.054) | (0.017) | (0.019) | (0.017) | (0.019) |
| PSNP labour | 0.416*** | 0.273** | 0.393*** | 0.233* | 0.122*** | 0.087* | 0.120*** | 0.086* |
| | (0.113) | (0.125) | (0.115) | (0.130) | (0.043) | (0.046) | (0.043) | (0.046) |
| PSNP cash | -0.117 | -0.199 | -0.153 | -0.193 | -0.074 | -0.146* | -0.089 | -0.147** |
| | (0.141) | (0.174) | (0.146) | (0.186) | (0.068) | (0.075) | (0.068) | (0.075) |
| Free food | -0.058 | -0.292* | 0.001 | -0.188 | 0.109** | 0.034 | 0.116** | 0.045 |
| | (0.145) | (0.158) | (0.141) | (0.150) | (0.047) | (0.060) | (0.047) | (0.059) |
| PSNP labour*CHIRPS deviations | | -0.264** | | -0.296** | | -0.076* | | -0.074* |
| | | (0.126) | | (0.131) | | (0.042) | | (0.042) |
| PSNP cash*CHIRPS deviations | | -0.127 | | -0.056 | | -0.115 | | -0.095 |
| | | (0.170) | | (0.184) | | (0.072) | | (0.072) |
| Free food*CHIRPS deviations | | -0.363*** | | -0.299** | | -0.100* | | -0.095* |
| | | (0.139) | | (0.136) | | (0.056) | | (0.056) |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Estimator | PC | PC | PC | PC | PDE | PDE | PDE | PDE |

Sales

| Usigma | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| CHIRPS deviations (IHS) | -0.221*** | -0.219*** | -0.226*** | -0.227*** | -0.089*** | -0.086*** | -0.091*** | -0.088*** |
| | (0.029) | (0.032) | (0.029) | (0.032) | (0.014) | (0.016) | (0.015) | (0.016) |
| PSNP labour | 0.120* | 0.124 | 0.105 | 0.103 | 0.059 | 0.048 | 0.058 | 0.044 |
| | (0.072) | (0.079) | (0.073) | (0.079) | (0.040) | (0.043) | (0.040) | (0.043) |
| PSNP cash | -0.008 | -0.069 | -0.03 | -0.072 | 0.013 | -0.018 | 0.008 | -0.021 |
| | (0.105) | (0.121) | (0.105) | (0.121) | (0.056) | (0.066) | (0.056) | (0.067) |
| Free food | -0.376*** | -0.358*** | -0.358*** | -0.321*** | -0.042 | -0.025 | -0.047 | -0.028 |
| | (0.083) | (0.097) | (0.083) | (0.094) | (0.042) | (0.049) | (0.042) | (0.049) |
| PSNP labour*CHIRPS deviations | | -0.002 | | -0.02 | | -0.03 | | -0.038 |
| | | (0.077) | | (0.077) | | (0.045) | | (0.045) |
| PSNP cash*CHIRPS deviations | | -0.11 | | -0.079 | | -0.053 | | -0.05 |
| | | (0.112) | | (0.113) | | (0.069) | | (0.069) |
| Free food*CHIRPS deviations | | 0.037 | | 0.078 | | 0.033 | | 0.038 |
| | | (0.089) | | (0.087) | | (0.047) | | (0.047) |
| Functional form | CD | CD | TLG | TLG | CD | CD | TLG | TLG |
| Estimator | PC | PC | PC | PC | PDE | PDE | PDE | PDE |

Profits

| Usigma | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| CHIRPS deviations (IHS) | 0.021 | 0.055** | 0.019 | 0.052** | 0.013 |
| | (0.023) | (0.025) | (0.023) | (0.025) | (0.016) |
| PSNP labour | -0.084 | -0.132* | -0.089 | -0.139** | -0.037 |
| | (0.064) | (0.069) | (0.064) | (0.069) | (0.043) |
| PSNP cash | -0.399*** | -0.346*** | -0.406*** | -0.348*** | -0.157** |
| | (0.090) | (0.102) | (0.091) | (0.102) | (0.068) |
| Free food | -0.380*** | -0.557*** | -0.367*** | -0.535*** | -0.213*** |
| | (0.076) | (0.087) | (0.076) | (0.086) | (0.047) |
| PSNP labour*CHIRPS deviations | | -0.078 | | -0.086 | -0.084** |
| | | (0.070) | | (0.070) | (0.040) |
| PSNP cash*CHIRPS deviations | | 0.113 | | 0.123 | 0.002 |
| | | (0.101) | | (0.101) | (0.063) |
| Free food*CHIRPS deviations | | -0.326*** | | -0.308*** | -0.150*** |
| | | (0.082) | | (0.081) | (0.045) |
| Functional form | CD | CD | TLG | TLG | CD |
| Estimator | PC | PC | PC | PC | PDE |