Land rights and the economic impacts of climatic anomalies on agriculture: evidence from Ethiopia

Mintewab Bezabih[1], Salvatore Di Falco[2*], Alemu Mekonnen[3] and Gunnar Kohlin[4]

[1]Environment and Climate Research Center, The Ethiopian Policy Studies Institute, Addis Ababa, Ethiopia, [2]Geneva School of Economics and Management, University of Geneva, Geneva, Switzerland, [3]Department of Economics, Addis Ababa University, Addis Ababa, Ethiopia, and [4]Environment for Development Initiative, University of Gothenburg, Goteborg, Sweden

[*]Corresponding author. Email: salvatore.difalco@unige.ch

Online Appendix

Appendix B: The propensity score matching and difference-in difference results

B1. The propensity score matching results

This section describes the process, and the results of the matching process in the propensity score matching (PSM) we employed in our analysis. As per our discussion in section 3, we have certification defined in two levels – the household and kebele levels. Accordingly, the matching process is done using these two levels. At the household level, the PSM approach uses the household-level certification as the treatment variable and socioeconomic and community-level variables as matching variables. A similar matching approach was used at the kebele level, with the treatment variable being kebele-level certification and the socioeconomic and community-level variables as matching variables.

As a result, the matching process gives us two matched samples – at household and kebele levels, which are used to conduct household- and kebele-level DiD analysis of the impact of certification on productivity conditioned on climatic factors. The matching approach employed in this analysis is the kernel matching method.

The main purpose of the propensity score estimation is to balance the observed distribution of covariates across households in the control and treatment groups. When involvement in the program is independent of outcomes, given the observables, then the relevant summary statistic to be balanced between the two groups is the conditional probability of participation, called the "propensity score" (Rosenbaum and Rubin, 1983). The first step of computing a propensity score in PSM is to estimate a standard probit or logit model of probability of being certified.

$$H_{it} = \alpha + K_{it} + v_{it}\,, \tag{A1}$$

where, for household i and year t, H_{it} is a dummy variable representing participation in the certification program or not; K_{it} is a vector of variables used as determinants of the likelihood of acquiring certification; and v_{it} is the error term. The predicted values are used to estimate the propensity score for each observation in the certified and the non-certified samples. The comparison group is then formed by picking the observation with similar characteristics for each participant (Jalan and Ravallion, 2003).[1]

The propensity score is given by:

$$e(x) = \Pr\,(w = 1)|X = x = E(w|X = x), \qquad \text{(A2)}$$

where *w* is the indicator of exposure to treatment, and *x* is the multidimensional vector of pre-treatment characteristics. The choice of covariates to be included in propensity score estimation is based on the principle of maintaining a balance in using common variables and at the same time meeting the common support criteria.

For each variable and propensity score, the standardized matching is computed before and after matching as:

$$SB(X) = 100 - \frac{\bar{X}_t - \bar{X}_{NT}}{\sqrt{\frac{\bar{V}_t(X) - \bar{V}_{NT}(X)}{2}}}, \qquad \text{(A3)}$$

where $\bar{X}_t$ and $\bar{X}_{NT}$ are the sample means for the treatment and control groups, and $\bar{V}_t(X)$ and $\bar{V}_{NT}(X)$ are the corresponding variance (Caliendo and Kopeinig, 2008).

The bias reduction (BR) can be computed as:

$$BR(100) = 100 - (1\frac{BX_{after}}{BX_{before}}). \qquad \text{(A4)}$$

As mentioned in the method section, the use of PSM allowed us to explore how the household- and village-level characteristics influenced the probability of having certification. Table B1 presents the logistic regression results of the probability of certification. The results suggested that some socioeconomic and village-level characteristics were significant in the probability of having certification at the household or kebele level. These significant variables are used in the

[1] Several matching methods have been developed to match participants and non-participants of similar propensity scores, all asymptotically yielding the same results (Caliendo and Kopeinig, 2008). In this instance, we choose the nearest kernel matching method.

matching exercise.

Table B1. Logit estimates of the probability of being certified (household- and kebele-level certification)

	Household-level certification	Kebele-level certification
Female household head	0.024	0.291***
	(0.100)	(0.097)
Age of household head	0.002	0.000
	(0.002)	(0.002)
Household head is illiterate	-0.013	-0.096
	(0.071)	(0.070)
Number of male adults in household	-0.030	-0.102***
	(0.032)	(0.031)
Total land area	0.023*	0.011
	(0.013)	(0.012)
Total number of livestock owned by household	0.006	0.068***
	(0.011)	(0.008)
Secondary school availability	0.055*	2.312***
	(0.033)	(0.144)
Piped water availability	-1.984***	-1.816***
	(0.152)	(0.083)
Water shortage	1.490***	-4.338***
	(0.087)	(0.199)
Community forest availability	0.510***	1.580***
	(0.185)	(0.105)
Distance from nearest market	-1.421***	0.000***
	(0.092)	(0.000)
Chi-squared	1257.773	1360.025
N	5288	5288
p-value	0	0

Notes: * significant at 10%, *** significant at 1%. Bootstrapped standard errors in parentheses.

Table B2. Propensity score matching results

Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Kebele-level certification								
Unmatched	0.186	1361.64	0	22.5	10.3	108.5***	0.73	57
Matched	0.053	363.78	0	16	8	55.6***	1.34	100
Household-level certification								
Sample	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%Var
Unmatched	0.176	1245.87	0	19.1	5.3	109.0***	1.12	63
Matched	0.048	410.26	0	11.3	8.6	51.5***	2.27*	75

Note: *** significant at 1%.

Table B2 presents results from covariate balancing tests before and after matching. The standardized mean difference for overall covariates used in the propensity score (around 19-22% before matching) is reduced to about 11-16% after matching. The p-values of the likelihood ratio tests indicate that the joint significance of covariates was rejected after matching. The pseudo-R2 also dropped significantly from 17-18% before matching to about 5% after matching. The low pseudo-R2 , low mean standardized bias, and high total bias reduction, suggest that the proposed specification of the propensity score is fairly successful in terms of balancing the distribution of covariates between the two groups.

Table B3. The impact of climatic anomalies and household-level certification on farm revenue (alternative cutoffs)

	Cutoff-0.5 to +0.5	Cutofff-1.5 to 1.5	Climate anomalies
Negative rainfall anomalies	-0.401***	0.108	-0.000
	(0.118)	(0.104)	(0.026)
Positive rainfall anomalies	-0.055	-0.943***	-0.010
	(0.130)	(0.293)	(0.068)
Negative temperature anomalies	-0.300***	-0.264	-0.159
	(0.100)	(0.170)	(0.132)
Positive temperature anomalies	0.008	0.279***	-0.011
	(0.068)	(0.088)	(0.012)
Post certification * Negative rainfall anomalies	0.268	-0.003	-0.079
	(0.197)	(0.178)	(0.132)
Post certification * Positive rainfall anomalies	-0.036	0.000	0.078
	(0.200)	(0.000)	(0.117)
Post certification * Negative temperature anomalies	0.580*	-0.008	-0.301
	(0.317)	(0.200)	(0.283)
Post certification * Positive temperature anomalies	0.517	0.077	0.018
	(0.386)	(0.162)	(0.079)
HH with certificate	-0.223*	-0.165	-0.067*
	(0.116)	(0.147)	(0.035)
Post certification	-0.281	0.096	0.411*
	(0.332)	(0.145)	(0.238)
YEAR FIXED EFFECTS	YES	YES	YES
CONTROLS	YES	YES	YES
MUNDLAK'S FIXED EFFECTS	YES	YES	YES
N	4861	4872	4868
R2	0.224	0.2273	0.2241

Notes: * significant at 10%, *** significant at 1%. Bootstrapped standard errors in parentheses.

Table B4. Pseudo treatment regression results and test of common trend assumption: log revenue analysis

$$lny_{ht} = \theta_{ht} + \beta x_{ht} + \gamma r_{ht} + \vartheta w_{ht} + \phi l_{t=i} * \vartheta p_k + \rho l_{t=i} p_k * r_{ht} + \partial l_{t=i} p_k * w_{ht} + \varepsilon_{ht} \quad (3)$$

Household-level certification		Kebele-level certification	
	Log revenue		Log revenue
Certified, year 2000	-0.928	Treated, year 2000	-1.713***
	(1.229)		(0.325)
Control, year 2000	-0.903***	Control, year 2000	-0.793***
	(0.124)		(0.130)
Certified, year 2002	-0.833	Treated, year 2002	-1.144***
	(0.691)		(0.265)
Control, year 2002	-0.893***	Control, year 2002	-1.042***
	(0.074)		(0.083)
Certified, year 2005	0.400***	Treated, year 2005	0.044
	(0.12)		(0.134)
Control, year 2005	0.655***	Control, year 2005	0.563***
	-0.094		-0.093
Positive temperature anomalies	-0.007	Positive temperature anomalies	-0.116**
	(0.050)		(0.057)
Negative temperature anomalies	0.140	Negative temperature anomalies	0.119
	(0.110)		(0.123)
Positive rainfall anomalies	-0.082	Positive rainfall anomalies	0.202**
	(0.080)		(0.100)
Negative rainfall anomalies	0.500**	Negative rainfall anomalies	0.322
	(0.212)		(0.231)
Certified, year 2000 * Positive temperature anomalies	0.189	Treated, year 2000* Positive temperature anomalies	0.913***
	(0.618)		(0.211)
Certified, year 2000 * Negative temperature anomalies	-0.336	Treated, year 2000 * Negative temperature anomalies	-0.934***
	(1.068)		(0.288)
Certified, year 2000 * Positive rainfall anomalies	-0.340	Treated, year 2000 * Positive rainfall anomalies	-1.742***
	(0.330)		(0.253)

Certified, year 2000 * Negative rainfall anomalies	-1.047*	Treated, year 2000 * Negative rainfall anomalies	-0.408
	(0.548)		(0.364)
Certified, year 2002 * Positive temperature anomalies	0.030	Treated, year 2002 * Positive temperature anomalies	-0.105
	(0.229)		(0.129)
Certified, year 2002 * Negative temperature anomalies	-0.745	Treated, year 2002 * Negative temperature anomalies	-0.234
	(0.591)		(0.233)
Certified, year 2002 * Positive rainfall anomalies	0.225	Treated, year 2002, and Positive rainfall anomalies	0.308
	(0.801)		(0.324)
Certified, year 2002 * Negative rainfall anomalies	-1.081*	Treated, year 2002 * Negative rainfall anomalies	-0.501
	(0.574)		(0.377)
Certified, year 2005 * Positive temperature anomalies	-0.043	Treated, year 2005 * Positive temperature anomalies	-0.418
	(0.185)		(0.369)
Certified, year 2005 * Negative temperature anomalies	-0.499	Treated, year 2005 * Negative temperature anomalies	-0.429**
	(0.608)		(0.212)
Certified, year 2005 * Positive rainfall anomalies	-0.034	Treated, year 2005 * Positive rainfall anomalies	-0.254
	(0.294)		(0.248)
Certified, year 2005 * Negative rainfall anomalies	-1.102**	Treated, year 2005 * Negative rainfall anomalies	-0.001
	(0.560)		(0.106)
CONTROLS	YES	CONTROLS	YES
N	5100	N	5212
Chi-squared	960	Chi-squared	1928
Prob>chi2	0	Prob>chi2	0
Test of common trends : climate-certificate interactions for 2000 , 2002 and 2005	***0.05***	***Test of common trends: climate-treatment interactions for 2000, 2002 and 2005***	***1.89***
Prob>chi2	***0.8185***	***Prob>chi2***	***0.1691***

Notes: * significant at 10%, ** significant at 5%, *** significant at 1%. Test of common trends in equations (3) and (4) in section 5.3 are represented by the coefficients corresponding to: climate anomalies-certificate interactions for 2000, 2002 and 2005 and Test of common trends: climate-treatment interactions for 2000, 2002 and 2005, respectively. The chi-square tests of the equality of the coefficients indicate that the assumption of common trends cannot be rejected. In other words, the outcome variable, farm revenue, moved in parallel in treatment and control areas before the program.

References

Caliendo M and Kopeinig S (2008) Some practical guidance for the implementation of propensity score matching. *Journal of Economic Surveys* **22**, 31–72.

Jalan J and Ravallion M (2003) Does Piped water reduce diarrhea for children in rural India? *Journal of Econometrics* **112**, 153–73.

Rosenbaum P and Rubin D (1983) The central role of the propensity score in observational studies for causal effects *Biometrika* **70,** 41–55.