Does forced solidarity hinder adaptation to climate change? Evidence from the Burkinabe cotton sector *

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Abstract

In semi-arid lands, resilience of farmers facing climate change is far from complete. The main objective of this paper is to explore whether sharing norms within a group of cotton producers imply adverse effects for the adoption of risk-mitigating strategies. These strategies can involve efforts to make existing forms of production more resilient to climate change (*incremental adaptation*), or endeavours to move across sectors and space to reduce vulnerability (*transformational adaptation*). I investigate the case of Burkina Faso where producers collectively purchase inputs from the cotton companies and pay back their loan under the constraint of joint liability. Specifically, I try to understand whether forced solidarity is correlated with the adoption of strategies that reduce exposure to climatic risks. From a sample of 668 smallholders, I proxied social pressure by the size of the network and find it to be associated with reduced investments in both incremental and transformational self-protection against weather shocks.

In rural areas of developing countries, many households integrate farming activities in their livelihoods and operate effectively as small firms. There are broad regions from Subsaharian Africa where climate change shapes the agricultural production and drives smallholders to reconsider their management systems in favor of more resilient strategies. Burkina Faso, where cotton production is at the core of many households' livelihoods, is one of them. In this country, policy makers target resilience to climate change as one of the main objective for the agricultural sector. For several reasons, agricultural management systems less dependant on climatic conditions are expected to generate significant welfare gains.

First, risk attached to agricultural activities reduces willingness to invest but marginal returns on investments could be important in terms of yields. Existing fieldwork and subsequent modelling from Burkina Faso suggest that returns from moderate increases in inputs and water availability are indeed high [Sanders et al., 1996]. Second, agriculture in Burkina Faso, and especially cotton production, is almost exclusively rain-fed. Since threats from climate change are very likely to grow there, any actions targeting less dependance on rainfall fluctuation has promise. Eventually, mitigating risks from climate change can prevent smallholders from falling into poverty traps. [Kazianga and Udry, 2006] brought evidence that households in rural Burkina Faso transfer rainfall shocks into consumption fluctuation. Levels of consumption and vulnerability are both highly linked to poverty. In Burkina Faso, poor farmers are particularly vulnerable since risks are large relative to their incomes. Aware of this potential loss, farmers may hold back on investment and miss profitable opportunities for higher income. This can lead to poverty traps.

Farmers undertake important strategies that help to mitigate or adapt to climate change. Some adaptation initiatives involve efforts to make existing locations, livelihoods and systems of production more resilient to climate change and are defined as incremental adaptations. Regarding the cotton production in Burkina Faso, incremental adaptations from smallholders could consist in improving soil and water conservation techniques, both crucial to an optimal crop growth. [1] However, supporting exclusively incremental adaptations may lead to a maladaptation response in a long term perspective since the risk of rainfall scarcity is expected to grow and threaten rain-fed agricultural production. Some authors argue that adaptation strategies in developing countries need to become more transformational instead of uniquely trying to preserve existing practices [Castells-Quintana et al., 2018]. By transformational, they refer to adaptation strategies that aim to reduce vulnerability to climate change through geographical and sectoral mobility of the poor. Some papers shed light on the need to strike a balance between the two forms of adaptation to make a system more resilient to climate change [Kates et al., 2012].

To reduce exposure attached to agricultural activities, self-protection and risk-pooling via both formal and informal structures are two usual approaches. In Burkina Faso, risk-pooling mechanisms have been implemented in the cotton sector to protect producers from negative shocks on their cultivated lands. Cotton farmers are gathered into formal groups to get access to inputs from cotton companies. At the end of the agricultural season, producers must pay back their own part of the loan to the company through harvested crops. The joint liability system is one of the key component of risk-pooling in this organization. It implies that crops failure from one farmer, following rain scarcity for instance, has to be supported by other members if necessary. Forced solidarity within the professional network allow farmers to mitigate harmful impacts from shocks. However, this service comes at a cost because of potential adverse incentive effects. Indeed, compulsory sharing generates free riding behavior by reducing incentives for self-protection as farmers can fall back on other members. Moreover, sharing obligations may dissuade farmers from working hard or investing in infrastructure as successful producers are likely to be solicited for assistance by their peers.

The purpose of this paper is to empirically investigate whether mutual assitance through redistribution reduce the ability to self-protect against climate change. In this context, redistribution pressure comes from the duty to shift yields toward members worst affected by negative shocks. To guide the empir-

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[1] The common soil and water conservation techniques in Burkina Faso include zai, mulching, diguettes (rock bunds), half-moons, and hedgerows.

ical analysis, I rely on a sample of 668 cotton producers from semi arid regions of Burkina Faso interviewed during the 2015/2016 agricultural season. Additional materials were collected to aggregate information at the group level. I rely on probit and instrumental variable models to show that sharing obligations invite free riding and attenuate incentives for self-protection against climate change. In other words, risk-pooling strategies operate at the expense of self-protection approaches to protect against climate change. This distortive effect impacts both incremental and transformational strategies, hampering the adoption of risk-mitigating strategies beyond the unique frame of cotton sector.

The remainder of this paper is organized as follow: Section 1 describes the organization of cotton producers in Burkina Faso and relates it to literature and theoretical intuition on forced solidarity. Section 2 introduces the data as well as the econometric strategy that serves the research question. In section 3, I discuss the main results along with some robustness checks. Eventually, section 4 concludes.

1 Context, Literature and Theoretical Basis

The system of Cotton Producers' Groups

For a landlock country such as Burkina Faso, cotton production has been a vital source of export earnings driving economic growth. Over the past few decades, this country has emerged as the largest cotton producer in West Africa. Being highly dependent on agriculture, this economy is threatened by the uncertainties that surround crop and livestock activities, such as weather, pests and diseases.

The Sudanian and Sudano-Sahelian agro-ecological zones are today the major places in terms of cotton production. With respectively average annual rainfall of 600-900 millimeters and 900-1100 mm, the Sudano-Sahelian zone is classified as a semi-arid region whereas the Sudano part displays characteristics of a subhummid environment (see Figure 1). Farmers are scarce in the Sahelian zone where arid environment creates harsh conditions for cotton production.

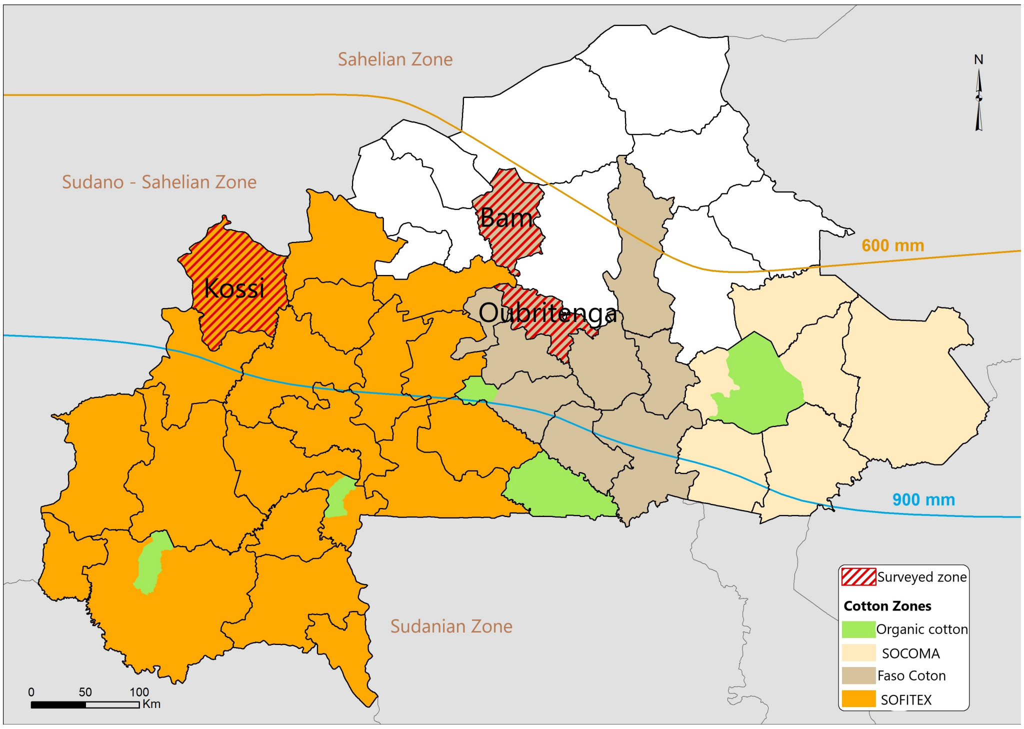

Figure 1: Map of Burkina Faso

Beginning with the French colonial period and persisting after independence, the Burkinabe cotton sector has been mainly owned and managed by French investors and local governments [Schwartz, 1996]. After the independence of Burkina Faso, SOFITEX, a government parastatal, together with a privately-owned French company (CFDT) were responsible for the cotton sector. The operation of cotton processing and marketing depicted a farming system in which SOFITEX provided all the inputs to cotton producers and were arrogated exclusive rights to purchase the cotton produced by the farmers [Schwartz, 1996]. Such a vertically integrated system eroded the benefits of cotton producers who were left with only a meager share of the world cotton price.

In 2002, new institutional arrangements mitigated the monopsony control of SOFITEX to open the cotton market to two other companies -Faso Coton and SOCOMA, each company operating in a different region of the country. At the same time, the Burkinabe government partially reduced its control to 35% to leave more space to other stakeholders in the leadership of the cotton sector. In this new environment, producers contribute to the negotiation of price levels through a farmer union called the National Union of Cotton Producers of Burkina Faso (UNPCB). Although some organizational transformation occurred, the cotton sector is still characterized by a high degree of vertical integration. Upstream, the cotton companies act as a monopsony by providing farmers with inputs, credit and extension services. Downstream, it operates as a monopoly by purchasing all the cotton harvest from the producers [Vitale, 2018]. Figure 1 illustrates the repartition of lands among the three cotton companies operating in Burkina Faso.

The recent emancipation of cotton producers in Burkina Faso occured following the reform in 1996. Before that, farmers were organized under cooperatives through village-scale joint-liability schemes called the GV ("Groupements villageois"). With the 1996 reform, former GV were replaced by groups/ cooperatives called Cotton Producers' Groups (GPC [2]). Under this new arrangement, cotton producers can group together following affinities and social preferences. Several GV were thus split into more local and compact social groups. Village minorities and newly established migrants were empowered through this reform as they eventually could create their own GPC. These new cotton producers' organisations, ruled by monitoring and joint liability, generated significant improvements both at the farm level [Kaminski, 2014] [Kaminski and Thomas, 2011] and on more aggregated agricultural indexes [Kaminski et al., 2011].

Therefore, every Burkinabe producing cotton belongs to a GPC. Within the group, producers are bounded by a joint liability towards the cotton company. Prior to planting, each farmer informs her GPC on the needs in terms of inputs, mainly seeds and fertilizers. Cotton firms provide the aggregated amount of inputs asked by every GPC that eventually redistribute them to farmers. At the end of the agricultural season, producers must pay back their own part of the loan through harvested crops. If one member of the group fails in providing enough crops to meet her duty, other producers from the same group take over the debts. This organization within the Burkinabe cotton sector is very close to the concept of group lending programs that provide a loan to an individual

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[2] GPC is the acronym of Groupements de Producteurs de Coton, the french and commonly used expression for Cotton Producers' Groups.

borrower who is itself a member of a borrowing group. This says that all group members are treated as being in default if any member of the group does not repay her loan.

Within cotton producers' networks, members can rely on assistance from others when necessary. In case a shock affects the income of one of the group members, the sharing rule dictates that other producers should provide assistance in the form of supplementary harvested crops. I expect these sharing norms to impact risk-taking and decisions of production of farmers threatened by climate change. Diverse hypothesis can be formulated concerning the consequences of such a system on resilience behaviors. The literature on group lending and forced solidarity provide tools to predict how such a system enforced in the Burkinabe cotton sector may affect risk-taking behaviors.

Literature on forced solidarity

Redistributive pressure within a network has economic implications. In the literature, [Besley and Coate, 1995] capture the idea that group lending may be able to harness social collateral. Under joint liability system, borrowers may fear the reaction of other group members. If the group is formed with a high degree of social connectedness, this may constitute a powerful incentive device, since the costs of upsetting other members in the community may be high. The fear of being socially sanctioned may enhanced cooperative members' incentives.

However, relatively effective members of social groups would face internal pressures to redistribute their incomes, which would create strong disincentives to apply effort, take risks, and accumulate capital [Platteau, 2014]. The sharing rule compels the more successful members to bear the burden of the least productive in the social network. The imperative to redistribute resources may come closer to an informal redistributive tax. Like any tax, this mechanism carries the threat of potential evasive response from the most prosperous members [Platteau, 2000] [Baland et al., 2011] [Squires, 2016]. Experimental evidence supports this view and investigates the magnitude of the economic impacts of social pressure to share income with kin and neighbors

[Jakiela and Ozier, 2016] [Beekman et al., 2015] [Boltz et al., 2019]. For instance, in Tanzania, [Di Falco et al., 2018] show that farmers with higher expected harvest discussed seed type with fewer people and obtained fewer actual harvest gains.

Following the literature, I can therefore distinguish two ways of managing production or income in response to redistributive pressure from the network. On the one hand, altruism creates an empathy effect with incentive to reduce the probability of having to draw on one member's resources. On the other hand, the free-rider effect stems from forced solidarity and captures both the temptation to rely on the efforts of other producers, as well as the disincentive to make efforts since returns from such investments might be shared with less successful members.

In Burkina Faso, sharing norms are generally strong [Englebert, 1996]. Empirical evidence from this country describes free riding patterns rather than an empathy effect in response to compulsory sharing. [Hadness et al., 2013] investigate the productivity level of a small sample of Burkinabe tailors depending on whether their prospective income was public information to their solidarity network or not. Their results show that compulsory sharing as well as the expectation of future claims for financial support significantly hinder entrepreneurial activity. Again, [Grimm et al., 2017] show that forced redistribution through family and kinship participates in reducing the ability to invest in enterprise capital in Ouagadougou.

An underexplored research question is the extent to which this evasive response may correspond to ill-suited economic decisions in the context of climate change. For instance, would individuals reduce their efforts dedicated to their cotton production to prevent resource sharing with their peers? Inversely, would they put additional efforts into production to avoid crop failure and assistance from other members? These interrogations emphasize the impact of the network on incremental adaptation strategies rather than transformational one. Indeed, the intuition first drives me to expect an impact of forced solidarity within farmers on decisions regarding the management of cotton sector itself, namely incremental adaptations. A further concern occurs when I consider transformational adaptations. That said, would the group lending scheme also hamper cotton growers from moving across sectors and space?

In this paper, I aim to fill this gap by exploring the behavioral and economic implications of redistributive pressure in the professional network. Professional network has been rarely considered as a source of pressure in academic studies, especially compared to kinship ties. I further contribute to the literature on forced solidarity by conducting a study in Burkina Faso where the economic implications of GPC has not been analyzed yet. Pointing out the adverse effects of group lending in agricultural activities is crucial since this form of organization is enforced in the whole country and act as a role model for neighboring countries involved in cotton production, such as Mali and northern Cameroun.

Theoretical Basis

In this section, I introduce theoretical fundations to have a glance at the impact of forced solidarity on the level of efforts involved in production. This is mainly inspired from the work developed by [Kaminski, 2007] where he simulates the role of institutions in the performance of outgrower schemes applied to the Burkinabe cotton sector. Although this model could be extended to alternative forms of organization or agricultural activities, the aim here is to better approach the design of farmers groups in the situation of the Burkinabe cotton sector. In this model, the focus is on the impact of the redistributive pressure, proxied by group size, on productive decisions. To match our case study, you can imagine the level of efforts as refering to the effort to adapt to climate change.

Under the condition that farmers can observe their partners' efforts, they know that there is a desirable Pareto-optimal level of effort they need to commit if they wand to maximize the joint-profit of the group: this is called the cooperative level of effort e^c. If farmers rather decide to maximize their individual maximizing-profit level, they play a non-cooperative game with level of efforts e^{nc}. The model first describes the simplest form under which the group include only two farmers and introduces extension to the group size later.

Let us consider that each cotton producer is endowed with one unit of land

and needs one unit of input to produce cotton. They either obtain successful harvest $Y = \overline{Y}$ with probability e or low yields $Y = \underline{Y}$ with probability $1 - e$. Producers chose actions, which can be thought as a level of effort $e \in [0, 1]$, for which they incure a strictly convex disutility cost $C(e) = ce^2/2$. Farmers are considered being risk neutral. Cotton companies and producers' unions establish the cotton fiber and input prices faced by farmers, respectively p and w. At the beginning of agricultural season, farmers take prices as given and make efforts in the production to pay back their debt. At the end of agricultural season, they are paid p for their output but input credit value w is subtracted from their payment. I assume that the farmer can repay her loan only when output is high enough ($Y = \overline{Y}$), otherwise she defaults and relies on her partners.

In the first case of two symmetric farmers linked by joint-liability agreement, the group defaults when both producers harvest few crops, such as

$$p\overline{Y} - w > 0 > p\underline{Y} - w \tag{1}$$

and,

$$p\overline{Y} - w > p(\overline{Y} + \underline{Y}) - 2w > 0 \tag{2}$$

Under the joint-liability agreement, each farmer's ex-ante expected profit π^i can be written as:

$$\pi^i = e^2[p\overline{Y} - w] + e(1 - e)[p\overline{Y} + p\underline{Y} - 2w] - C(e) \tag{3}$$

To make it clearer, both cotton producers realize successfull harvest $\overline{Y}$ with probability e^2 so that they earn $p\overline{Y} - w$. With probability $e(1-e)$, there is one producer defaulting so that player i receives her own surplus from successful harverst minus the other's deficit, $p\overline{Y} + p\underline{Y} - 2w$.

I derive the optimal efforts made by farmers when they are jointly liable to compare it to its counterpart in the case of larger groups. I solve the problem for both the cooperative and non-cooperative situations. Within the framework of cooperative efforts, the farmer maximizes the total welfare of the group which ultimately equals to consider the partner's effort as given and exogenous (noted $\overline{e}$). The optimisation of (3) offers the optimal non-cooperative effort e^{nc} as the solution of

$$\max_{e} \pi^i = e\overline{e}[p\overline{Y} - w] + e(1-\overline{e})[p\overline{Y} + p\underline{Y} - 2w] - ce^2/2 \tag{4}$$

Using the first order condition and stating $e = \overline{e}$ since farmer display symmetric characteristics,

$\overline{e}[p\overline{Y} - w] + (1-\overline{e})[p\overline{Y} + p\underline{Y} - 2w] = ce,$

it is now possible to find e^{nc} so that

$$e^{nc} = \frac{p\overline{Y} + p\underline{Y} - 2w}{p\underline{Y} - w + c} \tag{5}$$

The sufficient condition to ensure interior solution is

$$w - p\underline{Y} < p\underline{Y} - w < c. \tag{6}$$

In the case of endogenous effort from other farmer, the optimal cooperative effort is the solution of

$$\max_{e} \pi^i = e^2[p\overline{Y} - w] + e(1-e)[p\overline{Y} + p\underline{Y} - 2w] - ce^2/2 \tag{7}$$

It implies the following optimal level level of cooperative effort

$$e^c = max(\frac{p\overline{Y} + p\underline{Y} - 2w}{2p\underline{Y} - 2w + c}, 0) \tag{8}$$

with $e^c < 1$ under (6).

For the given parameters $(p, w, \overline{Y}, \underline{Y}, c)$, $e^c > e^{nc}$ if and only if,

$[p\overline{Y} + p\underline{Y} - 2w][p\underline{Y} - w + c] > [p\overline{Y} + p\underline{Y} - 2w][2(p\underline{Y} - w) + c],$

which is always true knowing (2).

Extension to larger groups : The theoretical model developed so far has considered the case of only two farmers and depicts a situation where efforts is supposed to be higher when farmers cooperate. The question is how efforts would evolve if there is a change in the size of the cooperative network? Now, I present the results of optimal level of efforts for n-symmetric farmers.

When turning from a one-to-one situation to a larger group, incentives for efforts are changed in both cooperative and non-cooperative contexts. More farmers in the group means both more members to share the deficit of defaulting producers and more numerous likely defaulty farmers. Thus, the size of the group impacts the probability distribution of ex-ante expected profits.

With n-symmetric risk neutral cotton producers, the cooperative effort resulting from joint-profit maximizing is solved for

$$\max_e \sum_{k=0}^{k=n/2} C_{n-1}^{k}[e^{n-k}(1-e)^k][p\overline{Y} - w + \frac{-k(w - p\underline{Y})}{n-k}] - C(e) \tag{9}$$

Under the cost function specified previously, the first-order condition that determines the optimal effort of a n sized group is

$$\sum_{k=0}^{k=n/2} C_{n-1}^{k}[p\overline{Y} - w + \frac{-k(w - p\underline{Y})}{n-k}][e^{n-k-1}(1-e)^{k-1}][(n-k)(1-e) - ke] = ce = \Gamma^c(e, n, \Omega) \tag{10}$$

where Ω is a vector of parameters $p, \overline{Y}, \underline{Y}$ and w.

If now, the farmers maximize their individual profit and take other's effort as exogenous, the new optimization problem is as follows:

$$\max_e e \sum_{k=0}^{k=n/2} C_{n-1}^{k}[\overline{e}^{n-k-1}(1-\overline{e})^k][p\overline{Y} - w - \frac{k(w - p\underline{Y})}{n-k}] - C(e) \tag{11}$$

The farmer's problem in the cooperative context leads to the following first order-condition

$$\sum_{k=0}^{k=A(n)} C_{n-1}^{k}[p\overline{Y} - w - \frac{k(w-p\underline{Y})}{n-k}]e^{n-k-1}(1-e)^k = ce = \Gamma^{nc}(e,n,\Omega) \quad (12)$$

The first observation is that $e^c > e^{nc}$ as long as $\Gamma^c(e,n,\Omega) > \Gamma^{nc}(e,n,\Omega)$ $\forall(e,n,\Omega)$. Thanks to previous assumptions made on Ω and the virtue of marginal costs being increasing with efforts, this finding remains true.

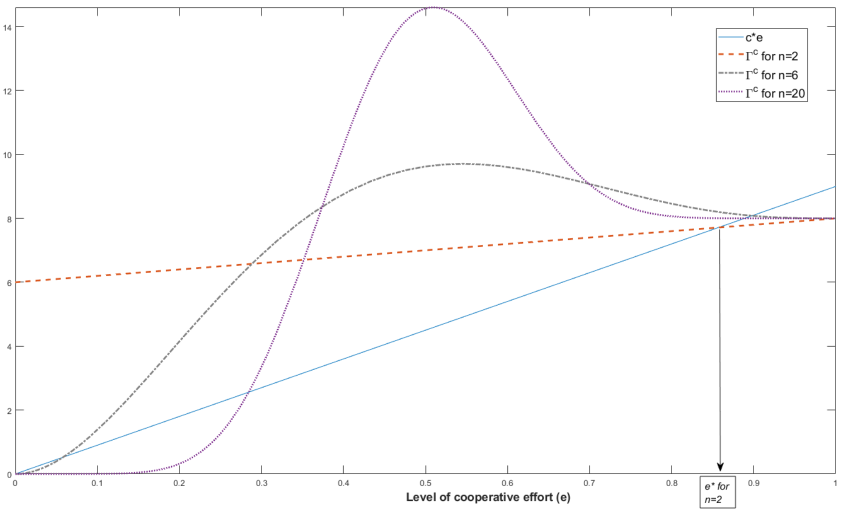

Figure 2: Cooperative equilibria of the n-player game.

From here, I analyze how optimal effort in both contexts (cooperative and non cooperative one) react to an increase in the size of the group. I simulate Γ^c and Γ^{nc} in figures 2 and 3 to graphically identify the optimal level of efforts according to different group sizes (for n=2, n=6 and n=20) [3].

Figure 2 shows that an increase in the size of professional network generates ambiguous effect on the optimal level of efforts chosen by the farmer. For instance, the optimal cooperative level of efforts equals to 0.86 when there are two only two farmers and increases up to 0.90 when the group extends to six members. However, there seems to be a network size threshold from which farmers belonging to larger groups start to reduce their optimal efforts on agricultural activities (see that $e(20) < e(6)$). Regarding the non-cooperative

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[3] To allow for simulations, I establish values to parameters in the vector Ω while respecting assumptions (1), (2) and (6).

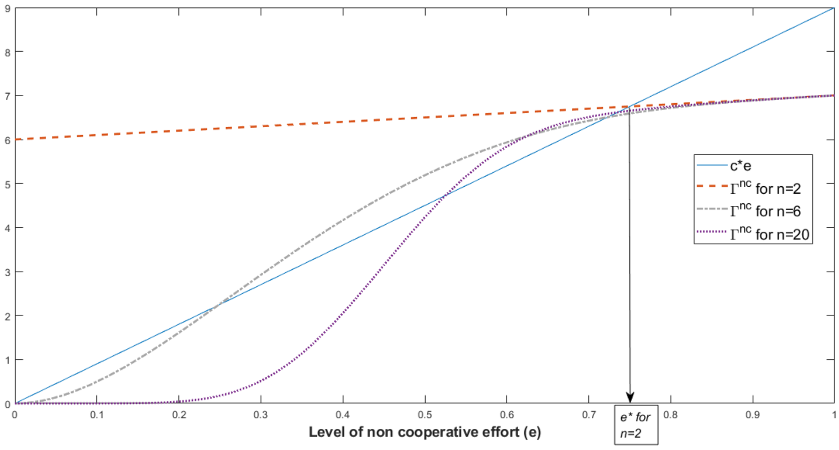

Figure 3: Non Cooperative equilibria of the n-player game.

framework, simulated optimal levels of efforts are firstly decreases with the size of the network before it increases again. However, optimal efforts in production in figure 3 are always lower than in the case of a 2-players game.

In what follows, I seek to test the prediction that cotton producers' ties affect self-protection against climate change in Burkina Faso. The econometric analysis helps to solve the directional amibiguity of this impact.

2 Data and the econometric model

The sample survey

Data for this study come from Pathways to Resilience in Semi-Arid Economies (PRISE), a multi-country research project that generates new knowledge about how economic development in semi-arid regions can be made more equitable and resilient to climate change [4]. Among other case studies, Burkina Faso has been considered in analyzing the cotton sector in Semi-Arid Lands. To be part of the survey, provinces from Burkina Faso needed to meet several criteria. First, they must be characterized by a semi-arid environment on request of PRISE project. Second, they should host some cotton producers [5]. Third, the

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[4] This project is led by Overseas Development Institute (ODI).

[5] Although this requirement sounds obvious, it is necessary to precise that some arid or semi-arid agroclimatic zones don't host any cotton producers because of harsh conditions

cotton companies operating in the selected departements should be SOFITEX and Faso Coton. Indeed, investigators worked closely with these two major cotton companies who both agreed to provide a list of cotton producers in the departements of interest.

Following the previous criteria, three provinces are represented in the survey: Kossi where SOFITEX operates, and Oubritenga and Bam where Faso Coton settled. In Oubritenga, households for which main economic activity consists in producing cotton locate in two departements: Nagreongo and Absouya. In total, these two departements count 160 farmers. The province of Bam has 475 cotton smallholders divided among five departements (Kongoussi, Rollo, Tikaré, Sabcé and Guibaré). Due to the small number of cotton farmers in these semi-arid regions, an exhaustive survey was initially considered there. However, out of the 635 enumerated farmers in these two provinces, only 524 were present at the time of the survey [6].

Unlike Bam and Oubritenga, the province of Kossi is a major cotton production zone with approximately 6033 farmers allocated between eight departements. According to information available from SOFITEX [7], only Nouna and Doumbala departements display characteristics of a semi-arid environment. Therefore, an aditionnal sample of 144 farmers who grew cotton during the 2015-2016 season was surveyed there. Eventually, 668 producers have been surveyed from December 2016 to January 2017.

Descriptive statistics for the independent variables are presented in Table 1. It provides information on several household characteristics - age, literacy, wealth indicators[8] –, as well as agricultural variables - the size of lands used for cotton production or labor used per unit of land. For the labor variable, the

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for this crop to grow.

[6] Also, investigators avoided to survey two producers from the same household. When two producers belong to the same household, they generally focus on the one refered as the head of the household.

[7] SOFITEX use its own devices to measure rainfall and temperature where its clients are located.

[8] Wealth index have been constructed following the methodology proposed by the DHS Program, taking into account characteristics such as assets and housing conditions. See `https://www.dhsprogram.com/topics/wealth-index/Wealth-Index-Construction.cfm`

survey distinguished between male and female employees and between family and rented employees, but I aggregate this information to one labor measure.

The summary table also presents links of the households with the outside world, including whether the household had access to early warning systems about extreme weather events. It introduces information on the perceived benefits of GPC system at individual level. Farmers were asked whether their GPC helps them to adapt to climate change. Later in the questionnaire, they were asked to identify three channels through which they take advantage of their GPC. For each category of benefits, I create dummy variable that equals to one if the producer has targeted this one among three choices [9].

Given the dependence on climatic conditions for farming success, I collected monthly rainfall and temperature data using GPS coordinates from the households. Data on rainfall were extracted from CHIRPS database from 1994 to 2016 and allowed to compute cumulative rainfall levels for agricultural season (from May to October) for each year [Funk et al., 2015]. I construct a ratio of average cumulative rainfall from 2005 to 2016 over average cumulative rainfall from 1994 to 2004. It helps to capture the evolution of rainfall during the last ten years compared to the ten previous one and match the timescale of the outcome variable. Data on temperature for the period 2005 – 2016 come from MOD11C3 MODIS and were used to establish monthly average temperature for the agricultural season too [Wan et al., 2015].

In addition to household questionnaires, investigators could establish the annual number of members per GPC since 2009 thanks to list of memberships provided by the two cotton companies. This information turned out to be precious to instrument the model and to check robustness. Unfortunately, some producers reported to belong to GPC that are not identified in the list provided by SOFITEX and Faso Coton.

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[9] The questions about help on climate change and channels are independant one from another. One farmer who answers that her GPC does not help to adapt to climate change can still choose three benefits from GPC.

Table 1: Summary statistics for independant variables

	mean	sd	min	max	Nobs
Self-reported number of members from the GPC	50.15	39.41	3	136	666
Mean Distance to other producers in the GPC	2.62	5.58	0	108	665
Age of household head (years)	49.00	12.63	18	88	660
Constructed Wealth Index	-0.00	1.76	-8	2	668
Farmer received education from primary school (1=yes 0=otherwise)	0.34	0.48	0	1	668
Access to Early Warning Systems (1= yes 0= otherwise)	0.52	0.50	0	1	668
Total labor per hectare used for cotton production	25.94	29.43	0	214	663
Land used for cotton production (hectares)	1.54	1.65	0	15	664
Information about the GPC environment					
GPC helps to adapt to climate change (1= yes 0= otherwise)	0.64	0.48	0	1	668
GPC fosters money transfers (1= yes 0= otherwise)	0.16	0.37	0	1	668
GPC fosters share of information (1= yes 0= otherwise)	0.52	0.50	0	1	668
GPC fosters provision of agricultural advices (1= yes 0= otherwise)	0.12	0.32	0	1	668
GPC fosters good relationships between producers (1= yes 0= otherwise)	0.18	0.39	0	1	668
GPC fosters provision of subsidized seeds (1= yes 0= otherwise)	0.25	0.43	0	1	668
Information about Climate					
Average cumulative rainfall 2005-16/Average cumulative rainfall 1994-2004	1.06	0.02	1.02	1.11	668
Average temperature for the rainy season over the period 2005 - 2016	34.66	0.54	33.13	35.51	668

Analytical Framework for the Adaptation Measures

In this section, I introduce the dependent variables. The survey aimed at analyzing cotton producers' adaptation strategies in response to evolution of climatic conditions in Burkina Faso. The questions investigate whether farmers noticed changes in temperature and rainfall trends since 2000. About 100% and 91% of the sample perceived such changes in mean rainfall and mean temperature respectively, which is consistent with the actual worsening of weather conditions. This observation is in line with [Kosmowski et al., 2016] who find that smallholders living in rural dry areas have a higher level of awareness of local changes. The farmers were also asked whether they had responded to these changes through adaptation measures within the last ten years. I use their answers to distinguish incremental adaption strategies from transformational one and analyze the impact of forced solidarity on both type of actions.

Intergovernmental Panel on Climate Change (IPCC) defines two categories of adaptation strategies in response to climate change [Field et al., 2014]. Incremental adaptations refer to "adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale". These strategies seek to preserve existing locations, livelihoods and forms of production while making them more resilient. In this context, systems keep their way of functioning with efforts towards more resilience to climate hazards and to climate change. Alternative definitions of incremental adaptations still come back to the spirit of IPCC view. For instance, [Fook, 2017] describes incremental adaptation as "adjustments made to manage proximate climate risks and impacts while retaining the function and resilience of existing structures and policy objectives".

In contrast, transformational adaptations illustrate actions that "changes the fundamental attributes of a system in response to climate and its effects" [Field et al., 2014]. Here, fundamental attributes refer to the function, structure and identity that characterize a system. By definition, agents carry out transformational adaptations when they seek to reduce vulnerability or exposure to climate change by replacing existing systems with new one. Within the context of this study, transformational actions might be transforming a system based on cotton production towards other economic activities. Transformational adaptations, mainly defined as movement of people and activities across sectors and space, describe a long-term process of economic development.

I initially expected redistributive pressure to have diverse effects on risk-taking whether it relates to cotton production or not. Indeed, although the sharing obligations from the professional network may impact the decisions relative to the cotton sector, it is not clear whether it would also hamper transformational adaptations. Therefore, I follow the previous definitions of incremental and transformational adaptations to classify the adaptation actions found in the questionnaire. I create two dummy variables, respectively for incremental and transformational strategies, equal to one if the farmer reported to have adopted at least one of the strategies refered in Table 2. Incremental adaptations focused on improvements in cotton management whereas transformational adaptations focused on alternative livelihoods strategies, substitution of crops, or relocation [10].

Table 2: Classification and summary statistics for adaptation strategies

Adaptation Strategies (Dummies)	**Mean**	**Std. Dev.**
Incremental Adaptation	0.792	0.406
Soil and Water Conservation Techniques	0.626	0.484
Change in rotation of crops, including cotton	0.588	0.493
Transformational Adaptation	0.609	0.488
Migration of at least one member of the household	0.001	0.039
Increase of temporary mobility	0.003	0.055
Adoption of new crops	0.133	0.340
Drop some crops	0.080	0.270
Diversification to other agricultural activities	0.451	0.498
Diversification to herd breeding	0.362	0.481
Diversification to off-farm activities	0.256	0.437
Total drop of agricultural activities	0.034	0.039

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[10] I exclude from the study adaptation strategies such as change in seeds and change in fertilizer since those inputs are distributed by cotton companies and do not reflect individual choices.

Econometric Strategy

The purpose of this paper is to empirically investigate whether professional network and joint responsibility reduce the willingness to self-protect in face of climate change. To estimate how the probability of adopting risk-mitigating strategies is affected by the extent of the professional network, I use the self-reported size of group and a set of controls. The extent of the network is represented by N_h while β is a vector of parameters and ϵ_h^i is a household specific error terms. Let A_h^i represent the i-th adaptation strategy (incremental or transformational) for household h. x_h,x_h^c and x_h^g are the vectors of household characteristics, climatic variables and GPC characteristics respectively.

The empirical model follows:

$$A_h^i = A(x_h, x_h^c, x_h^g, N_h; \beta) + \epsilon_{hi} \tag{13}$$

Specifically, N_h characterizes the self-reported number of members belonging to the same GPC for household h. Even though the self-reported size of the group may differ from the actual one, I believe that it constitutes a good proxy of the scope of the safety network upon which household h feels it can fall back in times of hardship.

The simplest identification strategy would assume that the size of one's producer network is exogenous. However, some work shed light on the group formation mechanisms that come to the fore when risk sharing is the objective. The theoretical studies highlight pre-exisiting social networks as a determining factor in group formation. [Attanasio et al., 2012] investigate who pools risk with whom when trust is crucial to enforce risk pooling arrangements. Both theoretically and empirically, they find that close friends and relatives are more likely to join the same risk pooling group, while unfamiliar participants group less and rarely assort. Therefore, risk sharing groups and professional networks are not randomly formed and correlate with networks of kinship, caste, friendship and geographic proximity [Fafchamps and Gubert, 2007], [De Weerdt and Dercon, 2006], [Munshi and Rosenzweig, 2009], [Mazzocco and Saini, 2012]. [Brun et al., 2001] and [Kaminski et al., 2009] support this view in the case of cotton producers' groups in Burkina Faso. Moreover, it is very likely that the kinship ties that drive producers to pool the risk together also impact decisions to adopt risk-mitigating strategies. [Di Falco and Bulte, 2013] bring evidence that compulsory sharing within family attenuates farmers' incentives to adopt soil and conservation (SWC) techniques. In such a context, the dependent and independent variables are correlated but the causal effects stem more from kinship ties that from professional network.

I challenge this issue by enforcing alternative specifications. I add several controls to attenuate the risk of omitted variables. Whereas I don't have enough information from the data to establish potential blood or kinship relationships between producers, I control for social connectedness by using GPS coordinates to compute distance between members from same group [11]. I follow the results from [Fafchamps and Gubert, 2007] to control interpersonal relationships with geographic proximity. Then, I control for inputs (land and labor) to capture wealth or endowments, as well as other socio-demographic variables. Given the dependence on climatic conditions for farming success, rainfall and temperature information allow to build an additional specification. [Asfaw et al., 2019] show that exposure to climate-related shocks in Sub-Saharan Africa is positively associated to transformational adaptations such as crop or livelihood diversification. In all specifications, I include a cotton zone fixed effects to control for unobservable heterogeneity at the Cotton Company Level (Faso Coton and Sofitex).

A step further consists in controlling for heterogeneity between group of cotton producers. Including fixed effects at the group level would allow me to tackle unobservable heterogeneity. Unfortunately, since some group of producers count very few members interviewed that all decide to either adopt or not, many observations are dropped out from the regressions. Instead, I use relevant answers from questionnaires to capture heterogeneity between group of producers. The survey gives intuition about the channels through which cotton producers take advantage of their group: GPC may bolster money transfers, good relationships between producers, share of information, provision of agricultural advice and/or better management of seeds. Considering the different

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[11] The distances are computed through a specific program in Stata using gps coordinates (geodist). The new variable created captures the mean distance from individual h to all other households belonging to the same GPC.

benefits at the core of each GPC, it may trigger different attitudes toward risk-mitigation.

The first assumption of exogeneity of the variable of interest is furthermore challenged by a reverse causality issue. Indeed, it is very likely that risk-lover agents would prefer big groups to make sure that they will have assistance from other members in case of failure in harvesting. That say, the main coefficient could illustrate the fact that risk-lover cotton producers chose larger groups to broaden their safety network.

Therefore, I decide to implement an instrumental probit approach to deal with possible endogeneity of the network variable. The selection of instruments is complex since I need a variable that is correlated with the professional network metric but not with the error term of the adoption models. As a first instrument, I decide to include the average self-reported size of GPC by commune, assuming that is correlated with GPC proxy but not necessarily with decisions to adopt resilience strategies. The second instrument is the lagged actual size of GPC back to the 2009/2010 agricultural season provided by the cotton companies (not self-reported) [12]. The size of GPC in 2009/2010 is likely to explain the self-reported number of members at the time of the survey (2015/2016). Whether it is correlated to error terms of adaptation measures is much more discussable since most of the strategies began to be implemented by cotton producers after the devastating flood in september 2009. Two of the surveyed provinces - Kossi and Oubritenga- belong to the regions the most affected by this extreme event. From the questionnaire, we note that 78% had to face significant damage from the flood. I provide test statistics to support the idea that instrumentation helps to strengthen the results in the case of incremental strategies, but keep in mind that neither instrumental variable is perfect.

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[12] Unfortunately, this information was not available for some groups and explains the drop in observations for regressions that use this variable

3 Results

Main Results

The main econometric results are reported in the tables 3 and 4. I focus on the effect of the number of members in the group of cotton producers on both incremental and transformational adaptation strategies. The first specification in each table presents the results for the most parsimonious model with household characteristics (1). Then, specification (2) controls for weather variables that are most likely to influence adaptation decisions. Model (3) introduces all the variables illustrating benefits heterogeneity between groups. Finally, the last model (4) introduces the results for the IV probit regression where I instrument for the network size variable.

The first result is that the self-reported size of the network is significantly correlated with a reduced probability to apply risk-mitigation strategies targeting the cotton production (table 3). This stands in contrast to previous studies which tend to conclude on a positive effect of measures of networks on the rate of adoption of new technologies [Boahene et al., 1999] [Isham, 2002]. Kin as well as non-kin members are taken into account in their proxy for social network whereas network is mainly professional in this study. This result survives all specifications including the instrumental variables model which satisfies the appropriate test statistics. Indeed, the Wald test highlights that the standard probit estimation results can be plagued by endogeneity bias (see at the end of table 3). To probe if the chosen instruments are relevant, I run the "first-stage regression" by regressing the network size variable against the instruments and the other exogenous variables. I found that both instruments significantly and positively correlate with the network variable, which motivates me to consider them as relevant [13].

I estimated the average marginal effect for the network variable, which equals -0.002. In other words, one new member joining the GPC reduces the probability of investing in incremental adaptation strategies by 0.2%. The

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[13] For the average of self-reported size of GPC per departement, coefficient is 0.242* with clustered standard error equal to 0.139. Regarding the actual size of GPC in the 2009/2010 agricultural season, the coefficient is 0.774*** with clustered standard error equal to 0.109.

negative effect of the network size seems therefore modest but should not be underestimated for two reasons. First, field observations prove that one member hardly decide alone to leave one group to join another one. Indeed, it is more likely that a whole small GPC asks to merge with another one to gain bargaining power in front of cotton companies. In this case, the marginal effect on the decision to strenghten cotton production resilience is more devastating. Second, existing fieldwork from Burkina Faso suggests that marginal returns on modest investments in water availability may be high in terms of yields [Sanders et al., 1996]. Therefore, negligence towards adaptation strategies, although small, can generate significant losses in yields.

Another interesting variable to analyze closely is the mean distance between one producer and her GPC partners. When the distance to other cotton producers increases, the household is significantly less likely to enforce risk-mitigating strategies for the cotton production. This results stands on several specifications. Being another proxy for social pressure, distance captures the similar idea that producers belonging to extended network (in space rather than numerally this time) have less incentive to consolidate their resilience to climate change. The average marginal effect approximates -0.005: being even further about one kilometer from other members decreases the probability to adopt incremental strategies by 0.5%.

Other variables deserve a quick look to complete the analysis of determinants to adapt in this context. Farmers working on parcels where temperature for the last ten years have been higher on average are significantly more likely to adopt incremental strategies. The rainfall levels do not impact significantly risk-mitigating strategies but it is important to repeat that producers have been surveyed based on their location in semi-arid lands. Therefore, they belong to climatic zones where rainfall patterns are very similar: it makes it more complex to capture the major role of rainfall in production decisions. Regarding the GPC environment, I notice one surprising result. Indeed, the likelihood to adopt resilient strategies for the cotton production decreases when smallholders are granted money transfers from the GPC. This can be explained by the pressure from GPC who agreed on money transfers as long as they are used to purchase new seeds or chemicals. Therefore, when provided with money transfers, cotton producers turn their back on the incremental strategies included in the outcome variable in favour of new inputs.

To conclude about incremental adaptation models, the results provide significant evidence of adverse incentive effects associated with forced solidarity. Under social pressure, farmers behave like free-riders and reduce their willingness to invest in more resilient methods for their cotton production.

Quite interestingly, and this is the second result, the estimates for transformational adaptations are qualitatively similar to the one for incremental adaptations (table 4). This result is robust to all specifications for the probit models, but not for the instrumental variable regression. However, results for the former model are not interpreted since we have no evidence of possible endogeneity in this case (see Wald test statistics at the end of table 4). Adaptation strategies that could be enforced in parallel to the one relative to the cotton sector are also negatively impacted by the network of cotton producers. In addition to hamper risk-mitigating strategies for cotton production, the structure of the professional network prevents smallholders from diversifying their activities towards other farm as well as non-farm activities. This means that the professional network impacts risk-mitigation strategies beyond the frame of the cotton production and constrain farmers to broadening their source of revenues. Roughly, the average marginal effect is such that one new member in the professional network significantly decreases the likelihood to enforce transformational adaptations by 0.3%. As explained previously, this seemingly modest result can generate significant consequences in farmers' livelihoods.

Two interpretations can support this surprising outcome. First, larger networks are more powerful and have more efficient ways to control for potential use of credit towards extra-activities. The use of distributed inputs for alternative crops would be severely repremanded - exclusion from the GPC for instance - and drive farmers to keep their focus on cotton production. Second explanation relies on the fact that cotton production is the main activity of the surveyed household. Cotton producers with a larger network have a bigger

Table 3: Regression for Incremental Adaptation to Climate Change

	Probit (1)	Probit (2)	Probit (3)	IV Probit (4)
Self-reported number of members	-0.005**	-0.007***	-0.007***	-0.009***
	(0.002)	(0.002)	(0.002)	(0.002)
Mean Distance	-0.009*	-0.011	-0.015*	-0.014**
	(0.005)	(0.007)	(0.009)	(0.007)
Age	0.019***	0.018***	0.018***	0.018***
	(0.006)	(0.005)	(0.005)	(0.005)
Wealth Index	-0.246***	-0.187***	-0.152***	-0.162***
	(0.065)	(0.058)	(0.054)	(0.055)
Education	0.209*	0.187	0.183	0.162
	(0.115)	(0.116)	(0.127)	(0.134)
Early Warning Systems	-0.173	-0.008	0.223	0.264
	(0.314)	(0.310)	(0.251)	(0.264)
Labor	0.001	0.002	0.000	0.000
	(0.004)	(0.004)	(0.003)	(0.003)
Lands	0.020	0.030	0.034	0.028
	(0.029)	(0.028)	(0.035)	(0.034)
Climate Environment:				
Rainfall Ratio		-12.691	0.699	-3.246
		(12.215)	(9.536)	(9.447)
Average Temperature		0.555***	0.474***	0.471***
		(0.183)	(0.167)	(0.173)
GPC Environment:				
Help against Climate Change			-0.272*	-0.210
			(0.165)	(0.184)
Money Transfers			-0.584**	-0.644**
			(0.270)	(0.266)
Share of information			-0.225	-0.235
			(0.290)	(0.314)
Provision of agricultural advice			0.272	0.182
			(0.351)	(0.346)
Better management of seeds			-0.051	-0.030
			(0.406)	(0.429)
Better relationships			-0.626***	-0.662***
			(0.229)	(0.246)
Fixed Effect for Cotton Zone	Yes	Yes	Yes	Yes
N	651	651	651	605
pseudo R^2	0.086	0.112	0.164	

Standard errors in parentheses, clustered at villages level.
Wald test of exogeneity (/athrho =0): chi2 (1) = 4.71 Prob > chi2 = 0.029.
Constant not reported.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

safety net upon which they can fall back in bad times. For other crops or activities, such a protecting system doesn't exist. Therefore, producers neglect alternative potential sources of income. In small groups however, cotton producers cannot rely on such an extended network. They generally concentrate in limited areas where they face common risks -such as lack of rainfall - that could bring the whole group to lose their cotton harvest. To plan for this eventuality, producers diversify their income sources and enforce transformational strategies to become more resilient to climate change.

Table 4 introduces other interesting determinants of the decision to adopt transformational strategies. This time, the degree of change in rainfall patterns seems to significantly impact adaptation decisions whereas temperature levels matter in specification (2) only. Producers working on parcels where rainfall has been more important for the last ten years compared to the decade earlier are significantly less likely to rely on extra- activities than cotton production. Moreover, observing the links of the producers with its GPC environment generates interesting comments. Certainly for the same reason as above, money transfers are not a vector of adaptation. Obviously, when distributing money to the farmers, leaders expect it to be invested in seeds or chemicals but not to flow towards alternative crops or activities. The only service provided by GPC that seems to help households to adapt their livelihoods to climate change is the share of agricultural advice.

Table 4: Regression for Transformational Adaptation to Climate Change

	Probit (1)	Probit (2)	Probit (3)	IV Probit (4)
Self-reported number of members	-0.008**	-0.009***	-0.007**	-0.005
	(0.003)	(0.002)	(0.004)	(0.005)
Mean Distance	-0.016	-0.021	-0.023	-0.015
	(0.020)	(0.014)	(0.023)	(0.015)
Age	0.006	0.003	0.001	0.001
	(0.005)	(0.005)	(0.005)	(0.005)
Wealth Index	-0.264***	-0.215***	-0.160***	-0.155**
	(0.077)	(0.042)	(0.059)	(0.063)
Education	0.259**	0.228*	0.158	0.186
	(0.109)	(0.120)	(0.126)	(0.140)
Early Warning Systems	1.002***	1.248***	1.148***	1.122***
	(0.268)	(0.135)	(0.198)	(0.214)
Labor	0.008	0.009***	0.007	0.006
	(0.006)	(0.002)	(0.005)	(0.004)
Lands	0.013	0.031	0.018	0.027
	(0.035)	(0.040)	(0.040)	(0.041)
Climate Environment:				
Rainfall Ratio		-31.648***	-26.410***	-28.258***
		(6.910)	(9.749)	(9.800)
Average Temperature		0.228	0.102	0.005
		(0.145)	(0.224)	(0.233)
GPC Environment:				
Help against climate change			0.235	0.292
			(0.235)	(0.249)
Money Transfers			-0.587**	-0.592**
			(0.290)	(0.297)
Share of information			-0.384**	-0.479**
			(0.197)	(0.223)
Provision of agricultural advice			1.106***	1.174***
			(0.402)	(0.417)
Better management of seeds			0.070	0.212
			(0.564)	(0.578)
Better relationships			-0.158	-0.114
			(0.322)	(0.337)
Fixed Effect for Cotton Zone	Yes	Yes	Yes	Yes
N	651	651	651	605
pseudo R^2	0.160	0.190	0.256	

Standard errors in parentheses, clustered at villages level.
Wald test of exogeneity (/athrho =0): chi2 (1) = 1.79 Prob > chi2 = 0.182.
Constant not reported.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Robustness Checks

In this section, I check the robustness of estimates by running additional regressions on the most complete probit specification (3).

Table 5 presents results for an alternative measure of network size. In this model, I test whether the results are robust to the actual size of network instead of considering the self-reported size of the network. I use information from the two cotton companies who enumerated the producers for most of GPC and allowed investigators to establish the actual size of groups. Unfortunately, this information was not available for some groups and explains the drop in observations compared to previous regressions. Results are qualitatively and quantitatively very close to what is previously found: they bring evidence of a free-rider behavior from producers belonging to larger groups.

As a further robustness test, I estimated a bivariate probit model. When we jointly consider the two adaptation strategies, the results are still consistent. The testing procedure on the correlation coefficient of the error terms indicates that we can reject the null hypothesis of zero correlation, meaning that the two adaptation strategies are often jointly undertaken. Table 6 presents results in line with previous findings.

At least, I test for more restrictive definitions of transformational and incremental adaptations to climate change in table 7. I condense incremental adaptations into one decision to adopt soil and water conservation techniques. This choice stands on the need to highlight impacts of network on strategies that clearly rests on the investment capacities of producers. Results bring the same conclusions: forced solidarity in larger groups invite producers to behave like free-riders and to avoid investments to strengthen resilience in their cotton production.

As a reminder, transformational adaptations are characterised by actions that "change the fundamental attributes of a system in response to climate and

Table 5: Robust Regression for Incremental and Transformational Adaptations - Alternative proxy for network size

	Incremental Adaptation	Transformational Adaptation
Actual number of members in the GPC	-0.009***	-0.009**
	(0.002)	(0.004)
Mean Distance	-0.014**	-0.018
	(0.007)	(0.017)
Age	0.016***	0.001
	(0.005)	(0.004)
Wealth Index	-0.154***	-0.171***
	(0.053)	(0.061)
Education	0.151	0.200
	(0.135)	(0.135)
Early Warning Systems	0.259	1.120***
	(0.272)	(0.231)
Labor	-0.000	0.007
	(0.003)	(0.005)
Lands	0.023	0.023
	(0.035)	(0.039)
Climate Environment		
Rainfall Ratio	-1.070	-25.352***
	(9.945)	(9.714)
Average Temperature	0.479***	0.057
	(0.164)	(0.212)
GPC Environment		
Help against Climate Change	-0.227	0.245
	(0.184)	(0.246)
Money Transfers	-0.608**	-0.607**
	(0.281)	(0.301)
Share of information	-0.257	-0.441**
	(0.299)	(0.214)
Provision of agricultural advice	0.221	1.065***
	(0.347)	(0.389)
Better management of seeds	-0.074	0.129
	(0.428)	(0.565)
Better relationships	-0.666***	-0.173
	(0.239)	(0.299)
Fixed Effect for Cotton Zone	Yes	Yes
N	614	614
pseudo R^2	0.173	0.258

Village Clustered Standard errors in parentheses
Constant not reported.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Biprobit Model for Incremental and Transformational Adaptations

	Incremental Adaptation	Transformational Adaptation
Self-reported number of members	-0.006**	-0.008**
	(0.002)	(0.003)
Mean Distance	-0.018*	-0.025
	(0.011)	(0.024)
Age	0.017***	0.000
	(0.005)	(0.004)
Wealth Index	-0.139***	-0.154**
	(0.050)	(0.061)
Education	0.197	0.168
	(0.125)	(0.122)
Early Warning Systems	0.237	1.156***
	(0.272)	(0.200)
Labor	0.000	0.008
	(0.003)	(0.005)
Lands	0.028	0.015
	(0.037)	(0.039)
Climate Environment:		
Rainfall Ratio	-1.968	-26.148***
	(8.982)	(9.354)
Average Temperature	0.466***	0.152
	(0.169)	(0.220)
GPC Environment:		
Help against Climate Change	-0.212	0.188
	(0.183)	(0.226)
Money Transfers	-0.529*	-0.628**
	(0.279)	(0.292)
Share of information	-0.245	-0.384**
	(0.323)	(0.187)
Provision of agricultural advice	0.361	0.991**
	(0.384)	(0.401)
Better management of seeds	-0.029	0.047
	(0.409)	(0.543)
Better relationships	-0.624***	-0.126
	(0.225)	(0.300)
Fixed Effect for Cotton Zone	Yes	Yes
athrho	0.864***	
	(0.111)	
N	651	

Village clustered standard errors in parentheses
Constant not reported.
Wald test of rho=0: chi2(1) = 60.76 Prob > chi2=0.00.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

its effects". This time, I exclude from the category any strategy that consists in reorganizing farming activities and focus on diversification to off-farm activities, total drop of agriculture, temporal mobility and migration. Following the new definition, the percentage of producers who adopted transformational strategies falls from 61% to 29%. Again, incentives to move across space and sector are significantly hindered by larger professional networks.

Table 7: Robust Regression for new measures of Incremental and Transformational Adaptations

	SWC Techniques	Transformational Adaptation
Self-reported number of members	-0.007***	-0.012***
	(0.002)	(0.003)
Mean Distance	-0.007	-0.036***
	(0.016)	(0.011)
Age	0.019***	0.003
	(0.005)	(0.006)
Wealth Index	-0.149***	0.051
	(0.049)	(0.062)
Education	0.166	0.122
	(0.129)	(0.120)
Early Warning Systems	0.701**	0.645***
	(0.286)	(0.187)
Labor	-0.003	0.009***
	(0.003)	(0.003)
Lands	-0.025	0.087*
	(0.039)	(0.046)
Climate Environment:		
Rainfall Ratio	-3.095	9.388
	(9.043)	(10.696)
Average Temperature	0.675***	-0.271
	(0.192)	(0.240)
GPC Environment:		
Help against Climate Change	-0.521***	0.088
	(0.142)	(0.210)
Money Transfers	-0.705***	-0.363
	(0.224)	(0.308)
Share of information	-0.160	-0.052
	(0.239)	(0.216)
Provision of agricultural advice	-0.017	0.324
	(0.212)	(0.344)
Better management of seeds	-0.085	-0.395
	(0.395)	(0.246)
Better relationships	-0.742**	0.138
	(0.288)	(0.295)
Fixed Effect for Cotton Zone	Yes	Yes
N	651	651
pseudo R^2	0.310	0.277

Village clustered standard errors in parentheses
Constant not reported.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4 Discussion and conclusion

The anthropological literature pioneered the idea that sharing norms may lead to distortive incentive effects and hold back investment in productive activities. More recently, economic researchers have investigated this question and evidence remains incomplete. In this paper, I test this idea by exploring the role of risk sharing network on the uptake of weather shocks management strategies in Burkina Faso. The results of this empirical analysis support the hypothesis that system based on forced solidarity between farmers may attenuate efforts to adopt techniques that reduce exposure to climate change. This conclusion stands for incremental as well as transformational risk-mitigating strategies, showing that the Burkinabe cotton system has behavioral and economic implications beyond its core sector.

Analyzing how sharing norms may become a barrier to adoption is crucial in the Sahelian context. Changing temperature and precipitation levels caused by climate change are expected to threaten rain-fed farming styles like cotton. It represents an important obstacle for the livelihoods and well-being of farmers in semi-arid lands. They react autonomously to changing environmental conditions by smoothing water availability for their crops or by switching towards activities or crops less dependant on rainfall levels. However, the existence of compulsory risk management devices may lead farmers to ignore self-protective measures. By requiring producers to gather in risk-pooling groups, cotton companies create pressure to redistribute the yields from the most productive farmers to the least successful one. Therefore, larger groups drive down the incentives to enforce autonomous risk-mitigating strategies.

In this paper, I do not reject the potential benefits of such a binding joint liability system, which can be a relevant form of safety nework when alternative market or institutional mechanisms fail to protect farmers. The aim is rather to highlight the existing trade-off encountered by producers due to the pressure to redistribute in case of successful harvest. Adressing the efficiency issue would have brought an important contribution to this study but researching this topic requires data for a careful comparison of all relevant marginal benefits and costs of strategies that are not available here. Based on intuition, I suppose that the adverse effects of sharing obligations on adaptation decisions could leave space to pareto-improved situations where both the farmer and its colleagues could be better off and more resilient to climate change. In the Burkinabe cotton sector, provision of alternative formal risk management devices, such as individual credit or index insurance, could spur decisions to adapt to climate change as it would relax network pressure on most productive farmers.

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