THE ROLE OF MIGRATION IN AGRICULTURAL INNOVATION FOR FOOD SECURITY

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Abstract

Despite the striking importance of migration and its socioeconomic and political implications, it is the least studied demographic phenomena in West Africa. Most recent studies in the developing world however indicated that the expansion of crop area will be severely limited; therefore, yield increases will have to account for most of the increases in production to ensure food security. The paper uses a detailed survey dataset collected in 2002 in Northeastern Burkina Faso and applies a treatment effects model that allows measuring the migration project effectiveness. Not directly linked with the adverse shocks that affect the local sending economy, migration is found to be a particularly relevant instrument to achieving larger stone bunds adoption for food security. Participation in migration may therefore be seen as a source of cash earnings to give value to the agricultural land. Results supported the importance of the free movement of labor in the regional integration process of the West African Economic and Monetary Union.

1. Introduction

Livestock and stored grain[1] are among the main forms of wealth available to Sahelian households to meet needs imposed by production shortfalls and periodic cash requirements. Because these sources have a very high covariation, in face of adverse climatic shocks households develop off-farm activities that ensure their food security[2] and allow agricultural investments. Comparing two similar groups in the Sahelian and the Sudanian zones[3] of Burkina Faso, Reardon, Matlon and Delgado (1988) showed that the Sahelian group was adequately nourished, while the Sudanian group was not. The results are explained by the role of non-cropping income (three quarter of the household income in the Sahel sample come from non-cropping sources). The latter is far from being a homogenous source because risk-averse households spread income risk not only across occupations, but also across locations. However, the occupational diversification has higher crop-based covariation in regional incomes, which makes it less attractive for coping with food insecurity. It is the purchasing power that ensures food entitlement and this can be delinked from the local cereal economy through migration. Labor migration is traditionally considered to be a way of protecting household members at the migrant's place of origin from economic pitfalls by receipt of remittances. Therefore, migration remains an important instrument in development strategy in the objective of reducing rural and total poverty. Alain de Janvry and Elisabeth Sadoulet (2001) found in their study of the Mexican Edijos communities that off-farm sources of income offer effective strategies to combat inequality and poverty and that seeking remittance income is a complement to land, expectedly to seek liquidity that enhances the productivity of land use. Forty six percent of the households interviewed in 2002 in my sahelian survey are participating in migration, which constitutes the main monetary income source in 22 percent of cases under study. Half of the households engaged in off-farm activities are indeed in migration, mostly to Côte d'Ivoire.

1 The main economic activities in the study area of Seno-Oudalan are extensive pastoralism and rain-fed agriculture, only possible in the short rainy season July-September (Hampshire 2002).

2 The analysis of food security has three dimensions, availability, accessibility, stability, in which availability is related to domestic production, import capacity, food aid, and stocks.

3 The West African Semi-Arid Tropics (WASAT) divides Burkina Faso from North to South in three agroecological zones that are the Sahelian, the Sudanian and the less drought-affected Guinean zone.

Analyzing the potential of migration strategies in stabilizing the income of rural households, Schrieder and Knerr (2000) found that these strategies are actually used as a substitute for missing financial and insurance markets, especially in cases of temporary migration in which the migrant remains an economic part of the household and the region of origin. The "New Economics of Migration" perceives labor migration with remittances as a strategy to secure and smooth the remittee's food consumption level and to provide capital for the remittee's farm investments. Dia (1992) describes a very efficient strategy to promote agricultural investments and reduce food insecurity and income risks by families in Senegal. They finance irrigation facilities through remittances from family members who are especially sent out for this purpose. This allows them to increase food crop production in a region frequently affected by droughts. In their study of the Malian Sahel, de Haan, Brock and Coulibaly (2002) also showed that the outcome of migration cannot be evaluated outside its relationship with the other livelihoods strategies, or the portfolio of household activities. Migration helped households to improve or maintain their livelihoods by stimulating and feeding into local productive activities.

Among off-farm income sources, the most important and less covariant with the local cereal economy is remittances from member migrants, either within the country or in foreign countries. In Burkina Faso, for the drought year 1984/1985, Reardon and Taylor (1996) showed that the share of migrant remittances in total income is much higher in the adequately nourished Sahelian zone (9 percent, compared to 1 percent in the Guinean zone). The 2002 survey I conducted indicated that families use remittances either for both consumption and investment (50.5 percent) or for consumption only (insurance motives). In line with the "New Economics of Migration", the objective of this paper is therefore to show how non-farm income sources play a crucial role in household's capacity to adopt farming technology, especially via migration. In the case of the 2002 survey, there is an important success in stone bunds adoption as 20 percent of farmers used this technology in the Sahel.[4] Therefore, technological change in crop production is understood in this study to be the construction of contour stone bunds for rainwater harvesting and soil erosion control. An understanding of the sources of

4 As background information, Diane-Dutilly, Sadoulet and de Janvry (2003) presented evidence of the benefits of adopting these technologies on household crop production and income. I further examine the determinants of adoption, given heterogeneity of the survey households.

agricultural productivity gains- and the role of off-farm financing is particularly important in areas exposed to food shortfalls and food insecurity such as the Sahel.

In section 2 of this paper, a brief review of literature on the links between migration and technological adoption in a context of risky environment and high transactions costs is presented. This section assesses the potential consequences of the migration strategy on technology adoption in food production. Section 3 presents the econometric approach in detail together with a short presentation the survey dataset. The variables used and their expected impacts are also studied. In section 4, the empirical results are analyzed. Finally, the concluding section 5 outlines the types of policies and strategies that could enhance the positive impacts and minimize the negative impacts of migration on rural development. Research directions that could widen the scope of the current study to face the food and environmental sustainability challenges in West Africa are recommended.

2. Non-local sources of income and food security: some theoretical foundations

Compared to the rural semi-arid Asia, Reardon and Taylor (1996) found that the West African Semi-Arid Tropics (WASAT) generally faces less developed rural capital and insurance markets, an extreme climatic variation, severe environmental degradation, a greater importance of livestock husbandry as an insurance mechanism, less availability of labor-intensive, low capital-input work for the poor and more equal land distribution. These environmental and economic factors create incentives for households to diversify their incomes outside the local crop economy through an outward-oriented diversification. Reardon, Delgado and Matlon (1988) summarized the following five possible "diversification push" factors in the Sahelian zone:

(a) low and unstable yields

(b) short growing season

(c) lack of irrigation

(d) credit/capital market failure and

(e) land constraints[5]

The authors concluded that diversification was driven by the need to compensate for bad harvests, and hence, was a reaction to a stagnating and risky agriculture. Liquidity for farm inputs and investments also imposes participating in off-farm activities as complement to peasants' farm activities. Stark (1991) argues that it is the migration of a family member that, by bypassing the credit and insurance markets and their bias against small farmers, facilitates the change and improves households' performance. Migration succeeds in accomplishing this via its dual role in the accumulation of surplus and, through diversification of income sources, in the control over the level of risk. Remittances act as an intermediate investment in-between technological investment, which has certain lumpiness and investment in financial assets, which has a low (or even negative) return. If remittances constitute a large share of total household incomes as in the case of Burkina Faso (Lachaud 1999), their potential impact on technological change in agricultural production is expected to be greater than if they are proportionately small. Stark (1991) formalized the migration benefits coming from remittances and showed a positive interaction between surplus insufficiency and averseness to risk. The easing of the surplus and risk constraints becomes a crucial condition for the small farmer to carry out desired technological change.[6] Just as bearing one risk makes individuals less willing to bear another risk, not bearing that one risk makes individuals more willing to bear another risk. This allows for experimentation at home with a relatively high-risk, high-return option, say, introducing a high-yield seed variety or adopting the stone bunds technology.

In the Sahel, households with liquefiable assets and cash crops are more able to diversify; implying credit markets constraints or failure. Therefore, the theoretical foundations of the local off-farm and migration strategies of households is often based on the aspect concerning market failures for credit and insurance that push households into

5 This factor is much more relevant in the Asian context where the rural poor lack access to sufficient land to make agriculture a viable income strategy. In Burkina Faso rural households practice rain-fed agropastoralism, under conditions in the northern Sahelian zone that correspond to a low but extremely variable rainfall, a fragile environment, and poor agro-climate.

6 See also Gubert 2000 for the limits of this analysis in the presence of moral hazard, especially in the context of geographically distant and permanent migration.

off-farm activities to diversify their risks and seek for sources of liquidity to be used in agriculture. This diversification strategy is facilitated in the new context of decentralization, local organizations, participation, and a demand-driven approach to the allocation of public resources.

Key, Sadoulet, de Janvry (2000) derived, using a static model that ignores the role of risk[7] and intra-annual credit constraints, the role of transactions costs[8] and missing markets in households diversification strategy, particularly their non-local activities. In a rural economy, the food supply is heavily constrained by labor shortages or food market accessibility. Therefore, in pure agricultural-based incentives system and in absence of labor or food market, peasants are not responsive to price incentives and opportunities to adopt new technologies for cash crop production. Constrained households cannot simply respond to price incentives and other external shocks and they are forced to shift the burden of adjustment on the good of the missing market (that is food and/or labor which the household controls). In this case no response on the targeted cash crop market is observed (de Janvry, Fafchamps and Sadoulet 1991) because the transaction costs make the market unusable by the household for the transaction. Each household will choose its own food or labor market strategy depending on the benefits with the results that some households may use the market (buyers and sellers) while others may not (self-sufficient). Because all households in a community tend to be net sellers or net buyers in the same year, a better coping strategy is found in activities that are not positively correlated with the risky local rural economy, which makes migration a particularly relevant income diversification strategy. Not directly linked with the adverse shocks that affect the local economy, migration is also a particularly relevant instrument to achieving larger technology adoption for food security. Participation in migration may therefore be seen as a source of cash earnings to give value to the agricultural land. Most recent studies in the developing world indicated that the expansion of crop area will be severely limited; therefore, yield increases will have to account for most of the increases in production to ensure food security. The solution is technological adoption in cereal crops

7 See Reardon and Taylor (1996) for some theoretical considerations on the effect of risk-averse behavior.

8 Many markets fail because the costs of using the market for a transaction are too high relative to the benefits the transaction yields. Transaction costs include not only transportation costs, but also the consequences of the opportunistic behavior that they allow (Sadoulet and de janvry 1995).

that has the potential to alleviate current and future problems of food insecurity by raising current levels of yield. Therefore, research on policies to boost smallholder productivity and their adoption in developing countries remains critical for food supplies, trade balances, and income among rural households (Rosegrant, Paisner, Meijer, and Witcover 2001).

One strand of the social learning literature suggests that adoption behavior depends on the risks involved. If a new technology is superior, adoption will occur.[9] However, if a potential adopter faces uncertainty about the outcome, there is an incentive not to adopt because of direct loss if the innovation fails. In addition, there is an indirect cost due to the loss of the adopter's network, since everyone else will continue to use the old technology. If there is uncertainty, people will consequently act in herds to avoid isolation (see the "penguin effects" in Choi 1997). However, Reynolds, Rajaram, and McNab (1996) and Reynolds, Rajaram, and Sayre (1999) argued that technologies that are beneficial may trickle down to all farmers; and if technologies are not yet beneficial, they may become so, as continuous population growth will ultimately necessitate increases in yield. In the particular case under study, stone bunds contribute to the natural resource management (NRM) in the Sahel, the latter comprising broadly agriculture-based management such as productivity investments and conservation investments (fertilizers, stone bunds); livestock related management and the use of the commons (combination agriculture-livestock-forest). The traditional and cost-effective technology of stone bunds enhances grain (millet and sorghum) yields; the Mossi introduced it in Burkina Faso in the early 20th century and interest in it was regained in the 1970s and 1980s in response to droughts and the important properties of the technology for rainwater harvesting and soil erosion control. Impacts on yields have been measured as between 40 percent and 100 percent depending on the region, the rainfall in the year of the study, and the spacing of stone bunds. The choice of which field is protected by stone bund is endogenous: partly the decision of the field owner himself, partly the result of the political process in allocating project benefits, and partly related to the physical

9 In the case under study, stone bunds that are an old well-established technology in the Mossi Plateau have been evaluated to increase crop yields on average for 40 to 100 percent (Dutilly-Diane, Sadoulet and de Janvry 2003).

characteristics of the field and its location in the village. In addition, stone bunds may create strong externalities, as collection of water run-offs and protection from soil erosion go beyond the field that the stone bunds actually surround. Because the presence of stone bunds on any field is an endogenous decision at the household level, this decision process can be modeled controlling for the community level influence.

Based on empirical evidence from Botswana, Lucas (1987) developed a pure migration model which postulates a combination of smallholder farming and migration as an income and investment strategy. He assumes that international migration is temporary and supplies a secure income, while farming is characterized by a permanent income risk. Migrants are assumed to invest in agriculture. The latter assumption is supported partly by the observation that migration is principally seasonal[10] in the Sahel and partly by the fact that rural areas in Burkina Faso are expanding as a consequence of the return of migrants to their places of origin (Traoré and Bocquier 1995). It therefore arises from the Lucas model that the impact of migration on the household's income situation in the short term is determined by the opportunity costs of the absent migrant, and in the longer term by the returns on investment financed out of remittance income. Reardon, Matlon and Delgado (1988) argued that Sahelian cultivation practices do not require intensive agricultural labor because it needs no clearing, and uses very little pre-season cultivation. Therefore, the opportunity cost of migration should be contained in any case. However, the functioning of such a family strategy requires that explicit and implicit contracts between the household members are adhered to.[11].

Additionally while the long-term food security strategy to invest part of the remittances in the family's farm enterprise has been largely observed in Sub-Saharan Africa, there is also evidence that the possibility of receiving remittances for securing food consumption in cases of bad harvest or declining prices promotes the introduction of cash crops which usually carry a higher risk than subsistence food cropping. The link between food production and innovation is actually not straightforward. With no market

10 The main characteristics that appear from national censuses and migration surveys allow describing West African migration as a temporary or circular labor migration (Cordell, Gregory and Piché 1996).

11 There are also a number of studies that examine the relative productive efficiency of the remittees households, assuming information asymmetry (Gubert 2000; Azam and Gubert 2002; de la Brière, Sadoulet, de Janvry, Lambert 2002). Information asymmetry should not be of key concern in the current study given that migrants are often the head of households and return home for the rainy season.

failures, a productivity gain in food leads to substitution in production away from cash crops to the production of food crops. Sale of a larger marketed surplus of food more than compensates for lower revenues from the production of cash crops and the consumption of manufactured goods increases. However, de Janvry, Fafchamps and Sadoulet (1991) used a numerical model to simulate the impact of a technological change in the production of food (as a result of remittances for example) and capture the essence of peasant behavior under market failures. Technological change or productivity gains in food production creates the perverse effect, under market failure, of inducing peasants to produce more cash crops while it would induce a commercial farm, or a peasant household with no market failures, to produce less cash crops. The conclusions are that under market failures, technological change in food allows production and consumption of more food, but it also allows the release of resources for the production of cash crops. Similarly, one of the main conclusions of the von Braun, Kennedy and Bouis (1989) study of the impact of cash crop production on food production by peasant households was that the promotion of technological change in the production of food crops is essential to allow smallholders to capture greater gains from market integration in cash crops. Under such circumstances, increasing the production of cash crops requires paying greater attention to the technological conditions under which food is produced.

From the previous theoretical discussions, it remains that migrant households are better able to self-insure against agro-climatic shocks either through investing in risk-reducing cropping strategies such as stone bunds adoption or to finance the entry cost into cash crop or noncrop activities.

Under risk and credit constraints, the nonmigrant poor households may want to diversify but cannot do so because of liquidity constraints. The difference can also be at the level of the timing of an innovation's introduction with nonmigrants being late adopters.

Finally, in the sahelian context of missing markets, market participation should be considered as a choice variable. The degree of vulnerability to cropping outcomes is inversely related to dependency on the market from both the income and expenditure side. Rather than being autarkic agriculturalists, Sahelian households rely largely on the market and purchase food to ensure their food security, especially during the slack season

(Reardon, Matlon and Delgado 1988). However, as explained in de Janvry, Fafchamps and Sadoulet (1991), producing households may have different relationships to the markets because of transactions costs. Transactions costs raise the price effectively paid by buyers and lower the price effectively received by sellers of a good, creating a price band within which some households find it unprofitable to either sell or buy, remaining therefore autarkic or self-sufficient. The heterogeneity in households market participation strategy is important in terms of households behavior in general and market response in particular because an autarkic household is perfectly price inelastic, and therefore measures of aggregate price response may underestimate price elasticity unless they account for the inelasticity of self-sufficient households. Price policies and agricultural policies in general will have very different behavioral and welfare implications for different sub-sectors of the farm population. Policies that reduce transactions costs are consequently important complements to price policies in affecting supply response. Each household determines its market participation by comparing the utility obtained from selling, buying, and remaining self-sufficient in this commodity. Specifying market participation as a choice variable allows incorporating these transactions costs into agricultural household model where the household decides how much of each good to consume, produce, and use as input as well as how much of each good to "market". Ignoring the heterogeneity of households' behavior on the food market would blur the results.

Using the 2002 survey,[12] I will now estimate the impact of migration on agricultural technology improvements controlling for market participation. A treatment effects model approach is used and the adoption equation is estimated conditional on off-farm non local migration participation and food market participation. The migration participation is estimated in a first step using a reduced form equation. Specifying migration as a choice variable allows incorporating migration impacts into an agricultural household model framework. Therefore the empirical strategy that follows is able to identify the impact of migration and transaction costs.

12 To control for emdogeneity and/or for theoretical relevance, some covariates were calculated using the first round of the survey in 2000.

3. Empirical model and estimation procedure

3.1 Econometric model of treatment effects

The empirical strategy in this paper is twofold:

- The choice of having a migrant member in the household (Côte d'Ivoire or any other destination).
- The choice of adopting stone bunds, essential for increasing crop yields and households livelihoods.

In this section, I present a treatment model where both the regression model and the selection model have a binary variable as the dependent. The specification assumes that migration has merely an intercept effect on adoption; then the appropriate model includes migration status as a right-hand side variable, and pools the entire sample of migration and nonmigration households. The robustness of the results is tested against a sample selection model specification. According to the latter, the migration effect does not show up as a dummy variable, but rather in the fact that the constant term and other coefficients may also differ from the migration to the nonmigration sub-sample. The results clearly showed a preference for the treatment model as will be discussed in the next section.

The treatment effects model allows measuring the migration project effectiveness. Following Greene (2000), an adoption equation that accounts for the value of a migration project is:

$$A_i = \beta' X_i + \delta M_i + \varepsilon_i \quad (1)$$

where M_i is a dummy variable indicating whether or not the household has a migration case.

The problem here is again one of self-selection and least squares estimates of δ would actually (under) over-estimate the migration effect, which is an individual household decision. The unbiased approach is the one of treatment effects methods that models migration participation (e.g., whether or not the individual household goes to migration) as

$$M_i^* = \gamma' w_i + w_i \quad (2)$$

$$M_i = 1 \quad \text{if} \quad M_i^* > 0, \quad 0 \quad \textit{otherwise}$$

u_i and ε_i are correlated.

The conditional expected adoption decision can then be written as

$$E[A_i/M_i=1]=\beta' X_i+\delta M_i+E[\varepsilon_i/M_i=1]$$

$$=\beta' X_i+\delta M_i+\rho\sigma_\varepsilon\lambda(\gamma' w_i) \quad (3a)$$

λ_i is the selectivity correction term and δ is the effect of migration.

To estimate this model, I use the two-step approach where the estimated δ accounts for the self-selected nature of migration participation unlike a simple OLS. For non-participants of migration, the corresponding adoption equation is:

$$E[A_i/M_i=0]=\beta' X_i+\rho\sigma_\varepsilon\left[\frac{-\phi(\gamma' w_i)}{1-\theta(\gamma' w_i)}\right] \quad (3b)$$

The difference in expected adoption between the two groups is estimated as follows:

$$E[A_i/M_i=1]-E[A_i/M_i=0]=\delta+\rho\sigma_\varepsilon\left[\frac{\phi(\gamma' w_i)}{\theta(1-\gamma' w_i)}\right] \quad (4)$$

As previously mentioned, a simple OLS estimation of equation (1) would lead to an over (under)estimation bias of the coefficient of the treatment dummy variable M_i by the following positive (negative) amount:

$$\rho\sigma_\varepsilon\left[\frac{\phi(\gamma' w_i)}{\theta(1-\gamma' w_i)}\right]$$

The bias depends on the direction of the correlation between migration and technological investment. Whereas the recent literature in the Sahelian context argues that migration is pro-development (short term improvement of purchasing power, long term effect on food security through investments in fertilizer and stone bunds when credit market does not function), the conventional view is that migration is a loss of labor force that may discourage adoption.

In implementing the above treatment model, I first estimated the probability of having a migrant in the household for the entire sample of migrant and nonmigrant

households and included the predicted outcome in an adoption model. The latter is estimated using a simple OLS method with parametric bootstrapping methods to recover consistent standard errors of the estimates.

The following two regressions are estimated:

$$\Pr ob(M_i = 1) = \gamma' w_i \tag{5}$$

$$E[A_i / M_i = 1] = \beta' X_i + \delta \hat{P}(M_i = 1) \tag{6}$$

The bootstrapping motivation

The estimation of models that contain unobservable variables may either replace the latter by their predicted values from an auxiliary statistical model or estimate them jointly with the relationship of first interest. Even though computationally less-costly, the Two-Step method fails to account for the fact that the unobservable covariate (net benefit of migration) has been estimated from an auxiliary econometric model in calculating the second-step coefficients and standard errors. The imputed unobservable applied in the second step are therefore measured with sampling errors and the subsequent hypothesis tests are incorrect (Murphy and Topel 1985). Naïve uncorrected procedures would vastly exaggerate the precision of the second step estimates for the imputed key-regressors and therefore bias the subsequent inference.

A convenient method of calculating asymptotically correct standard errors in Two-Step models is the bootstrap of the standard errors. The bootstrap procedure hinges on the assumption that the observed distribution is a good estimate of the underlying population distribution. The method produces an estimate of the sampling distribution, which permits to estimate the standard errors of the coefficients. The accuracy of this procedure depends on the number of observations in the original sample and the number of replications in the bootstrap. It is generally believed that replications in the order of thousands produce very good estimates. To obtain the bootstrapped standard errors of the estimates, I need to produce the desired estimates given a sample. I then draw thousand samples with replacement based on the data, repeatedly executing the estimations, and collecting the bootstrap results (Stata Press 2003). The bias is estimated as the difference between the average of the bootstrapped statistics and the original observed statistic.

Bootstrapping provides a way of estimating standard errors for statistical inference without affecting the original point estimates.

3.2 Short description of the data

Despite the striking importance of migration and its socioeconomic and environmental implications, it is the least studied demographic phenomena in West Africa. The available statistics are not up to date and hardly allow one to study the evolution of the phenomenon. However the NESMUWA[13] survey (1993) showed that the most important flows occur between Côte d'Ivoire and Burkina Faso, with 3.2 millions migrations, that is, half of the total flows inside the network. This is confirmed in the household and village level surveys that I conducted in 2002 in Northeastern Burkina Faso. The current empirical work is based on the total sample of 115 migrant[14] and 135 nonmigrant households and distinction is made between households that do (20 percent) or do not use stone bund. Because the survey was first conducted in 2000, some variables were constructed using the 2000 data to avoid endogeneity problems.

3.3 Variables used and expected outcomes

Following the household model (under large transaction costs on food markets) derived in Dutilly-Diane, Sadoulet, and de Janvry (2003) for the same households,[15] the estimations of each of the two equations may contain explanatory variables classified in the following categories: prices and transaction costs (regional market effects and distance to the nearest local town for the influence of the political sphere); shifters in consumption and farming (number of dependents, exogenous transfers, yield, quality of cooperation in the management of common property pastures, land availability, household characteristics); and regional dummies. Additionally, the estimations of innovation under risky environment, migration and market strategies call for inclusion of risk variables, land quality, community level characteristics and other family characteristics.

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13 Network of Surveys on Migration and Urbanization in West Africa.

14 In which, 13 households have a member in other destination than Côte d'Ivoire, representing 11 percent of the sample.

15 The authors used the data from the first round of the same survey they conducted in 2000.

Table 1 presents the results of mean comparison for the two observed groups of nonadopters and adopters of contour stone bund. Table A1 presents similar results for migration decision while tables A2 and A3 are the respective related descriptive statistics.

Table 1: Joint test of difference between non adopters (N=200) and adopters (50)

Variable	Mean_nonadopter	Mean_adopter	t	P_value
Price and transaction costs				
distance to the market	17.75	16.98	0.48	0.63
distance to regional capital	34.26	36.2	-0.64	0.52
Shifters in consumption and farm production				
dummy, non-member remitted money and/or inkind	0.07	0.06	0.39	0.70
available labor force 2002	6.13	7.62	-2.21	0.03*
ethnic group	8.85	12.18	-4.07	0.00*
formal cooperation 2000	0.22	0.25	-1.51	0.13
effective cooperation 2000	0.65	0.69	-1.3	0.19
average age of household	36.06	33.60	2.57	0.01*
dummy public school or literacy	0.16	0.24	-1.21	0.23
density household	0.04	0.05	-1.43	0.16
external project innovation support	0.02	0.74	-11.46	1.04e-15*
number of quarters	5.05	5.06	-0.02	0.98
total number of plots per household	2.23	2.66	-1.55	0.13
Market participation, soil quality and risk variables				
food buyer	0.98	0.88	1.99	0.05*
heterogeneity in community livestock	2467.75	13381.69	-1.78	0.08*
percentage of rules made in collaboration with chief and organization 2000	0.89	1.81	-1.58	0.12
village dominant in clay soil	0.17	0.28	-1.51	0.14
village dominant in poor degraded soil	0.40	0.34	0.85	0.40
Percentage of households land in poor degraded soil	0.25	0.29	-0.65	0.52
Percentage of households land in sandy soil	0.53	0.45	1.16	0.25
field under fallow 2002	0.28	0.34	-0.73	0.46
low rainfall, dry oudalan	0.45	0.24	2.98	0.00*
medium rainfall, north seno	0.23	0.28	-0.63	0.53
Income variance in 2000	1.64e+11	1.58e+11	0.25	0.80
migrant household	0.45	0.5	-0.63	0.53

* Significant difference at a minimum of 90 percent confidence level.

The next table 2 suggests the expected outcomes of the above variables from the theory.

Table 2: Expected signs of included variables

Variable	Migration decision*	Stone bunds adoption
Price and transaction costs		
distance to the market		-
distance to regional capital		-
Shifters in consumption and farm production		
dummy, non-member remitted money and/or in-kind	-	+
available labor force 2002	+	+
ethnic group	+	
formal cooperation 2000	-	
effective cooperation 2000	-	+
average age of household	-	-
dummy public school or literacy	+	+
density household	+	
external project innovation support	-	
number of quarters	+	-
total number of plots per household	-	+
Market participation, soil quality and risk variables		
food buyer	+	-
Percentage of households land in poor degraded soil	+	
Percentage of households land in sandy soil	-	
field under fallow 2002	-	
low rainfall, dry oudalan	+	-
medium rainfall, north seno	+	-
income variance in 2000	+	-
migrant household		+

*variables not signed are used as instruments for the market participation behavior estimation.

Table 6-1 and Table A3-1 (Appendix) show that household who adopted the stone bunds as well as migrant households have significant higher labor assets than their counterparts. Both groups are also younger on average. Adopters generally benefited strong support from external public projects even though this is not the only reason for adoption. On the other hand, migrant households are more educated than nonmigrants and own relatively higher amount of plots assets. Migrant households also have higher endowments in sandy soil, favorable to millet cultivation. The assumption here is that soil

quality[16] controls for the important biophysical factors that determine crop yields such as nutrients, water, pests, diseases, weed infestation, lodging, and other stresses. While adopters are less engaged in food market as buyers, migrant households show more access to food market. Similarly, the community of adopters exhibits relatively higher heterogeneity in livestock holdings, which is not the case for migrants. Heterogeneity in community livestock holdings is constructed at village level as the sum of the squared values of the differences between the maximum herd size and the median herd size per quarter. Finally, there are fewer households who adopt when the climate is not favorable as in dry and low rainfall Oudalan whereas this region pushes relatively higher number of households to migrate. This is confirmed by the fact that migrant households experienced higher income risk.

4. Estimation results

Finally the estimations are presented here in three steps:

1. Probit regression of the migration selection rule is used to produce the predicted migration outcome.
2. Estimates of the adoption of stone bunds include the important heterogeneous behavior of households toward migration. Table A4 tested the implicit assumption of using a pooled sample of migrants and nonmigrants against the alternative that migrant households may self-select and migration may not be random regarding adoption behavior. The latter is rejected, which means that the current two-step method is more efficient.
3. The outcomes of the adoption regression are obtained using Ordinary Least Squares and a bootstrapping method is used to derive the corrected standard errors.

16 The survey asked farmers about the soil texture (proportion of sand, clay, and silt given by local classification of soils as Seeno, Ceekol, Bolaare); however, soil properties also include nutrient balances such as nitrogen, phosphorus, potassium, acidity, organic matter, and moisture levels. It should be noted that part of the nutrients are added also by farmers through the use of green manure and fertilizer.

4.1 Migration choices

In the case of the treatment effect models using two-step consistent estimators, identifying restrictions would be needed for the migration selection probit. The identifying variables are density of households in the village and ethnic group. The density of households in the village captures the expected positive effects of population density while the ethnic groups control for the tradition and network effects. These identifying variables are all believed to strongly affect the chances for migration (the cost of migrating, the reservation income and therefore the net benefit) in the model but they may not influence the adoption pattern. Although it is well known that for instrumental variables estimation, one requires a variable that is correlated with the endogenous variable, uncorrelated with the error term, and does not affect the outcome of interest conditional on the included regressors, identification in sample selection issues is often not as well grounded. Because the Inverse Mills Ratio (IMR) is a nonlinear function of the variables included in the first-stage probit model, then the second-stage adoption equation is considered identified because of this non-nonlinearity even if there is no excluded variable.

Participation in off-farm activities and in particular migration (see Janvry and Sadoulet 2001) is a function of the characteristics of the household, the asset position, and the regional characteristics of the community where the household is located. Household assets are classified as land, human capital, and migration assets, social and institutional assets. The model specification of migration decision incorporates as well the impact of market participation and its potential endogeneity[17] as households self-select into buyer/non-buyer position. Then one should instrument for market participation using two-step methods, as shown in tables A5 and A6. In table A5 in Appendix, the test of endogeneity of buyer strategy in household migration decision is conducted. The first step result is presented under regression 1 where the instruments used are distance of the village to the market and heterogeneity in community livestock holdings. Unlike the case for livestock and nonfood consumption, households are diverse in their food position and

17 Endogeneity refers also to the fact that market participation is potentially a choice variable, correlated with unobservables relegated to the error term. But market participation cannot be modeled here because only 1.74 percent are not food buyers and are self-sufficient, whereas only 6 percent sell food.

it is the high transaction costs that influence household market participation strategies as seller, buyer, or self-sufficient. This justifies the inclusion of distance to market as an instrument.[18] In a second step, regression (2) evaluated the effect of the residuals from the food buyer regression in the migration equation. The statistical test clearly could not reject the orthogonality assumption but one can suspect two explanations: the poor diversity in the market participation regime (actually more than 98 percent of the sample are food buyers) or the weakness of the available instruments. Despite the test results, it makes sense to proceed in instrumental variables estimation and test for the validity of the instruments. Table A6 presents instrumental variables estimation of the household migration decision. The subsequent overidentification test could not reject the validity of the instruments.

The final results are presented in the following table 3, which analyzes the migration prospects of the 115 migrant households, among whom 90 percent move to Côte d'Ivoire. Results indicate that this strategy of diversifying income sources outside the Sahel positively depends on the household's labor resources, its human capital, the density of households in the village, the ethnic network, relative scarcity of rainfall, and the income risk. On the other hand, migrants would stay home if the household of origin is relatively old. However, the coefficients estimated in the migration probit measure how the log-odds in favor of migrating outside the Sahel change as the independent variables change by a unit. For interpretation, marginal effects need to be computed (Long and Freese 2001). Column 3 in the table 3 calculates the average marginal effects as changes in the probability of migration. The household's age negatively affects the propensity of the household to migrate, whereas human capital in the form of public schooling or alphabetization favors migration. The analysis focuses on the existence of at least one educated member within the household. Basu and Foster (1998) argue that only one person needs be educated in the household for the entire household to benefit from the cognitive skills acquired in school. However, lagged income risk (captured through the variance of income in 2000) plays a positive role in the migration decision. Given recurrent droughts in the Sahel, households cope with the high instability of their income

18 For instrumental variable estimation, one requires a variable that is correlated with the endogenous variable, uncorrelated with the error term, and does not affect the outcome of interest conditional on the included regressors. All external instruments had no effects in the migration equation.

(income variance) by sending more migrants outside their geographical zone, mainly Côte d'Ivoire. This confirms that it is purchasing power that ensures food entitlement and this can be delinked from the local cereal economy. In the rural semi-arid Sahelian village of Zaradougou in Mali, de Haan, Brock and Coulibaly (2002) found that for decades migration to Côte d'Ivoire has been a central part of household strategies integrating the village into an economy that spread across political borders, straddling different agro-ecological zones.[19] Most households employed a large proportion of their active labor force to work on their second farms in Côte d'Ivoire. Zaradougou households owned up to on average 18 hectares of plantation in Côte d'Ivoire and during the agricultural season 1997/1998, households dedicated 34 percent of their active labor force to these plantations, and 31 percent of households defined the plantations as their most important source of income. At the same time, households' labor plays a positive role in migration. As underlined in Hampshire (2002) labor force is the second most important wealth in Seno-Oudalan (following livestock husbandry) and households with many economically active people have greater productive and reproductive potential and these large households also have the potential to diversify economically, and spread risks, which can be critical in reducing vulnerability to crises. Finally table 3 indicates that higher ethnic network increases participation in migration especially abroad. Extra-household networks in sending villages can be called upon to plug labor deficits left by migrants and to provide small amounts of credit for migrants to meet travel costs (Hampshire 2002). In the survey I conducted in Côte d'Ivoire in 2002, the sample households usually discovered migration through information received from a close relative already living in Côte d'Ivoire (52 percent), other Burkinabè migrant (4.2 percent), or a return migrant (28 percent). Therefore, migrants also rely on networks at the destination to help them established and find work and to provide cheap accommodation.

19 Most of the long-established households had developed a livelihood strategy based on cultivation of cotton and grains around the village, combined with plantations in different parts of Côte d'Ivoire. Twelve out of the 16 households in Zaradougou farm one or more cocoa and coffee farms in a different agro-ecological zone, effectively reducing risks.

Table 3: First step regression of household migration decision

	(1) migrant household+	(2) Marginal effet dF/dx
Number of quarters	0.012	0.005
	(0.34)	(0.34)
average age of household	-0.037	-0.015
	(-2.69)***	(-2.69)***
available labor force 2002	0.077	0.031
	(2.52)**	(2.52)**
food buyer+	0.669	0.241
	(1.40)	(1.40)
low rainfall, dry oudalan+	1.256	0.470
	(4.69)***	(4.69)***
Medium rainfall, north seno+	0.633	0.248
	(2.55)**	(2.55)**
density household	8.861	3.514
	(3.41)***	(3.41)***
Ethnic group	0.036	0.014
	(1.99)**	(1.99)**
Income variance in 2000	1.15e-12	4.56e-13
	(2.07)**	(2.07)**
dummy public school or literacy+	0.526	0.207
	(2.07)**	(2.07)**
Constant	-1.662	
	(-2.08)**	
Observations	250	250

z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
+ Indicates dummy variable.

The predicted migration outcomes coming from the previous first-stage equation is then included to consider the effect of an endogenously chosen migration treatment on the technology adoption model, conditional on the set of other independent variables.

4.2 Stone bunds technology adoption

Because former studies measured the positive impact of the traditional contour stone bund on yields between 40 percent and 100 percent, it is interesting now to study the key factors in adoption behavior at household level, especially the differences between migrant and nonmigrants.

Table 4: Household adoption decision

	adoption of stone bunds+
Number of quarters	-0.017
	(-1.83)*
average age of household	-0.001
	(-0.15)
Available labor force 2002	0.012
	(1.36)
food buyer+	-0.388
	(-3.10)***
low rainfall, dry oudalan+	-0.325
	(-3.80)***
Medium rainfall, north seno+	-0.180
	(-2.22)**
Income variance in 2000	-1.04e-13
	(-0.67)
dummy public school or literacy+	-0.019
	(-0.26)
Predicted migration	**0.131**
	(2.33)**
Constant	0.816
	(4.10)***
Observations	250
R-squared	0.14

T statistics in parentheses
* Significant at 10%; ** significant at 5%; *** significant at 1%
+ Indicates dummy variable.

Therefore, the appropriate model includes migration status as a right-hand side variable and one can then proceed to estimate the stone bunds adoption (a dichotomous choice of 'adopted' or 'never adopted') regression equation via OLS corrected for biased standard errors. The corrections are based on 1000 replications of the bootstrap (see tables 4 and 5).

After the bootstrap correction, the results in table 5 of stone bund adoption show that participation in the food market as a buyer has a significant negative impact on a household's adoption of the stone bunds technique. This means that in opposition to self-sufficiency or the seller regime, access to the market as a buyer may bring households to diversify their activities in less risky sectors that provide them with purchasing power (off-farm activities or livestock farming). In the Burkinabè Sahel where nearly all the farmers are buyers, it is well-known that off-farm incomes are the most important sources of liquidity that allow households to purchase their subsistence food (Reardon, 1994). Additionally, households that are not primarily engaged in farming may have lower

probabilities of investing in farm innovations than those for whom farming is the primary activity. As opposed to buyers and argued by Finkelshtain and Chalfant (1991), many risk-averse households (probably the self-sufficient in the current study) are likely to produce more food when food prices are risky, in order to protect themselves against consumption-price risk.

Table 5: corrected t-statistics for household adoption decision

Bootstrap t statistics for stone bund adoption (see table 6-4)				
regressor	**observed coefficient**	**estimated bias*100**	**proportion estimated bias[1]**	**bootstraped t**
available labor force 2002	0.01	-0.02	-0.03	1.21
Average age of household	-0.001	-0.01	-0.02	-0.15
dummy public school or literacy	-0.02	-0.23	-0.03	-0.24
food buyer	-0.39	-0.55	-0.04	-2.57**
income variance in 2000	-1.04e-13	6.27e-13	0.04	-0.68
low rainfall, dry oudalan	-0.33	-0.19	-0.02	-3.61***
Medium rainfall, north seno	-0.18	-0.19	-0.02	-2.02**
number of quarters	-0.02	0.005	0.01	-1.83*
predicted migration	0.13	-0.07	-0.01	2.15**

[1]estimated bias above 25% of the standard error indicates serious distortion.

Concerning the direct impact of rainfall, the households living in the driest zones of the Sahel (low rainfall) have relatively lower incentives as well to adopt stone bunds and allocate their scarce resources in food production. Instability and insufficiency of rainfall in the Sahel make agriculture less profitable and therefore play a negative role in the adoption of stone bunds. Households from regions of lower rainfall (province Oudalan and northern Seno) have relatively higher propensity to migrate and send back money that is partly used for innovation and directly increase their income. But these effects should be distinguished from the direct negative effects of low rainfall.

Age of the household was also controlled since adoption behavior may differ for an older generation following the Chayanovian life cycle. The latter stated that peasant households contained families with different age structures, and that those households also farmed different quantities of land (Perz 2000). The propensity to adopt new technology may consequently depend on the laborer to consumer ratio in households. This declines as households get older. Unfortunately, schooling capital of households

appears to have no direct significant impact on their adoption behavior. This unexpected result is explained in Weir and Knight (2000) who investigated the role of schooling at the household- and site-levels in the adoption and diffusion of agricultural innovations in rural Ethiopia. They also found that household-level education is important to the timing of adoption but less crucial to the question of whether a household has ever adopted fertilizer, i.e. early innovators tend to be educated and to be copied by those who adopt later,[20] obscuring the relationship between education and adoption at the household-level. They however found that the externality effect (site and neighborhood levels) of aggregate education is substantial. It should be recalled as well that the education effects are strongly positive on the first stage migration decision and may act indirectly through migration strategy. The other non significant explanatory variables are non-constant and in some cases current values of such variables may not reflect at all conditions at the time when the adoption decision has been taken. It is known that the participation to stone bunds activities is primarily a village level decision but controlling for village engagement into stone bunds project did not work here (innovation support from an external project). It is important to note that among the households engaged in stone bunds, 26 percent did not benefit from external support, which may indicate that that not all the households engaged in stone bunds are from villages where such a project exists. I included the number of different quarters or neighborhoods per village that is a proxy for the size of the community. The number of neighborhoods in each village was determined directly by the survey questionnaire based on the distribution of households within the site. The larger a community, the more difficult it is to organize collective action. The lack of cooperation and efficiency in natural resources management can hinder the construction of stone bunds which needs community labor participation. The negative effect of number of quarters on adoption indicates that efficiency in resource use is obtained by cooperation (Ostrom 1993), the latter becoming more difficult to achieve under big group size. These aspects need further examination because the negative influence of the number of quarters may hide other community-level specific

20 Evidence to support that early adopters tend to be more educated than late adopters or non-adopters was provided in the ordered probit analysis of the probability of being an early adopter. To do so, they collected historical recall data on the timing of adoption, in particular, information on the year in which each household adopted fertilizer.

heterogeneities. Other common pool resources management results in McCarthy, de Janvry, and Sadoulet (1998) show that the index measuring the degree of cooperation has more explanatory power than a dichotomous cooperate/not cooperative specification, indicating that there are different qualities of cooperation among communities. Following this line, I use indices of effective and formal cooperation estimated in Dutilly-Diane, Sadoulet and de Janvry (2003) for the same households. However the effects did not turned significant for migration and adoption. This is not surprising as common pool resources are primarily relevant for activities such as livestock farming.

The interesting result here is that migration is the best argument for technological adoption. The survey showed that remittances are used both for consumption and investments, and the current finding indicates that these investments partly concern agricultural and natural resources management activities, that is, stone bunds technology. The direct effect of the loss of family labor through migration is compensated because most of the migrants are absent only for the slack season and it is shown in the migration equation that bigger households are likely to migrate and therefore suffer less from labor constraints. The main message here is that Sahelian households diversify their income sources outside the agricultural sector to search for funding they invest in agriculture while at the same time they ensure a sustainable local agro-ecological risk management especially when the migration destination is Côte d'Ivoire. However, the most remunerative migration which is international has substantial capital requirements; with the danger of leaving the poor with the less remunerative and scantier work opportunities closer to home (Taylor, 1987). Further complications are the recent development of return migration and its consequences on future remittances flows. Households should be prepared to face this forced shift in income sources away from migration toward other diversification mechanisms or back to crops and livestock. They need to be encouraged to invest in agricultural productive inputs and technology. Failure to substitute for the risk of fall in the remittances can provoke the same short-term reaction observed during drought years (1984/1985 for example), that is, distress sales of livestock by the poor who will have to push hard on a meager resource, depleting one very important self-insurance mechanism. This will create enormous inequality as rich households are under

less pressure to liquidate their livestock holdings because of their ability to self-insure against negative shocks through other means.

5. Conclusions

This paper tackled a current important regional issue in West Africa concerning the food security[21] through an examination of the links between income diversification strategies, in particular migration and NRM through stone bunds adoption. The results showed that if Sahelian households have access to migration, this promotes a significant higher adoption rate that enable households to ensure their food security through the direct channel of food production and the indirect channel of food market where they may have better access and purchasing power. In most of the developing world, expansion of crop area will be severely limited, so yield increases will have to account for most of the increases in production. Therefore, research on policies to boost smallholder productivity in developing countries remains critical for food supplies, trade balances, and income among rural households (Rosegrant, Paisner, Meijer, and Witcover 2001). In the Sahel the ultimate goal of agricultural innovations is food security. In addition, Reardon and Taylor (1996) showed that increasing crop income reduces inequality in the Sahel.

Given the dependence of the poor on the cropping base, policies and development programs should focus on improving productivity and building more resistance to agroclimatic shocks into the Sahel agricultural system. The latter involves removing barriers to entry (access to credit and human capital formation) for the poor into nonfarm income activities. The strategy of promoting nonfarm enterprises is complementary with promoting agriculture in these zones (Reardon and Taylor 1996).

Policy makers can reduce the incidence of market failures for specific households by the channel of infrastructure investments, increased competitiveness among local merchants, and the better circulation of information on prices. They can also eliminate indirect sources of market failure by increasing access for peasants to credit markets and to markets for insurance or rising the diversification opportunities for farmers. The latter needs regional institutions to consider serious actions to favor the free movement of labor. This study gives support to the development strategy in the Sahel that promotes

21 IFPRI's 2020 Vision for Food, Agriculture and The Environment.

non local income diversification through migration and call for instruments that direct remittances investment into efficient and cost-effective traditional agricultural technologies.

However, the policy-makers face two set of complications when trying to favor the migration outcomes. Under the conditions that households must self-finance their diversification, the poor may want to diversify for risks reasons but cannot do so because of liquidity constraints. Political interventions are therefore necessary if one wants to use noncrop income as a tool to reduce total income inequality and promote natural resource management. Further complications are the recent development of return migration and its consequences on remittances flows. Given that the data were collected a few weeks before the start of the current political crisis in Côte d'Ivoire, the migration challenge is an urgent matter, as recent forced return migration in all of the West African landlocked countries may worsen the food and environmental situation. One way to address such a politically important issue is certainly to widen the scope of the current research. First, because return migrants have specific skills and are typically entrepreneurial, it is necessary to carry a survey that focuses on the returnees' strategies at home. Second, food insecurity is often a problem faced by the poorest of the poor, who may be disadvantaged in both biophysical and human resources. The poor vulnerable households deserve special attention that can be captured within general modeling and decision support tool such as the Multi-Agent Systems that allow modeling of the entire diversity of biophysical conditions as well as the entire diversity of households. General modeling allows also for further development of the current research that includes estimates of supply response that are needed to predict the impact of policy changes on production in a context of heterogeneous participation of households to the market.

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6. APPENDIX

*A*1 Statistical analysis of explanatory variables

Table A1: Joint test of difference for the migration groups

Variable	Mean_nonmigrant	Mean_migrant	t	P_value
Price and transaction costs				
Distance to the market	16.05	19.42	-2.58	0.01
Distance to regional capital	34.95	34.30	0.26	0.79
Shifters in consumption and farm production				
Dummy, non-member remitted money and/or inkind	0	0.16	-4.60	0.00
Available labor force 2002	5.71	7.29	-3.63	0.00*
Ethnic group	9.30	9.77	-0.62	0.54
Formal cooperation 2000	0.23	0.23	-0.29	0.77
Effective cooperation 2000	0.65	0.67	-0.52	0.60
Average age of household	37.14	33.72	3.96	0.00*
Dummy public school or literacy	0.10	0.27	-3.55	0.00*
Density household	0.04	0.05	-2.87	0.00*
External project innovation support	0.16	0.16	0.14	0.89
Number of quarters	5.10	4.99	0.30	0.76
Total number of plots per household	2.16	2.50	-1.95	0.05*
Market participation, soil quality and risk variables				
Food buyer	0.93	0.98	-1.99	0.05*
Heterogeneity in community livestock	7116.35	1694.69	2.12	0.03*
Percentage of rules made in collaboration with chief and organization 2000	0.88	1.31	-1.47	0.14
Village dominant in clay soil	0.27	0.10	3.53	0.00*
Village dominant in poor degraded soil	0.35	0.44	-1.53	0.13
Percentage of households land in poor degraded soil	0.24	0.27	-0.73	0.46
Percentage of households land in sandy soil	0.45	0.58	-2.42	0.02*
Field under fallow 2002	0.30	0.29	0.29	0.77
Low rainfall, dry oudalan	0.29	0.55	-4.25	0.00*
Medium rainfall, north seno	0.22	0.27	-0.86	0.39
Income variance in 2000	1.23e+11	2.10e+11	-3.64	0.00*

Notes:

- Significant difference at a minimum of 90 percent confidence level.
- Number of nonmigrants (135) and migrants (115)

Table A2: Descriptive statistics of variables used in Chapter 6[22]

Variable	Stone Bunds adoption	N	Percent missing	Mean	Standard Deviation
Price and transaction costs					
Distance to regional capital	Nonadopters	200	0.00	34.27	20.00
	Adopters	**50**	**0.00**	**36.20**	**18.78**
Distance to the market	Nonadopters	199	0.50	17.75	10.60
	Adopters	**49**	**2.00**	**16.98**	**9.98**
Shifters in consumption and farm production					
Dummy, non-member re-mitted money and/or inkind	Nonadopters	200	0.00	0.07	0.26
	Adopters	**50**	**0.00**	**0.06**	**0.24**
Available labor force 2002	Nonadopters	200	0.00	6.13	3.00
	Adopters	**50**	**0.00**	**7.62**	**4.50**
Ethnic group	Nonadopters	200	0.00	8.86	6.01
	Adopters	**50**	**0.00**	**12.18**	**4.94**
Formal cooperation 2000	Nonadopters	199	0.50	0.22	0.18
	Adopters	**49**	**2.00**	**0.25**	**0.12**
Effective cooperation 2000	Nonadopters	199	0.50	0.65	0.24
	Adopters	**49**	**2.00**	**0.69**	**0.17**
Average age of household	Nonadopters	200	0.00	36.06	7.40
	Adopters	**50**	**0.00**	**33.60**	**5.65**
Dummy public school or literacy	Nonadopters	200	0.00	16.00	
	Adopters	**50**	**0.00**	**24.00**	
Density household	Nonadopters	200	0.00	0.04	0.04
	Adopters	**50**	**0.00**	**0.06**	**0.05**
External project innovation support	Nonadopters	200	0.00	1.50	
	Adopters	**50**	**0.00**	**74.00**	
Number of quarters	Nonadopters	200	0.00	5.05	3.00
	Adopters	**50**	**0.00**	**5.06**	**3.01**
Total number of plots per household	Nonadopters	200	0.00	2.23	1.17
	Adopters	**50**	**0.00**	**2.66**	**1.87**

22 The first row records results concerning nonadopters, whereas the second row is about adopters of stone bund techniques.

Table A2: Descriptive statistics of variables used in Chapter 6[23] (continued)

Variable	Stone Bunds adoption	N	Percent missing	Mean	Standard Deviation
Total number of contour stone bund	Nonadopters	200	0.00	0.00	0.00
	Adopters	**50**	**0.00**	**1.48**	**1.09**
Market participation, soil quality and risk variables					
Food buyer	Nonadopters	200	0.00	97.50	
	Adopters	**50**	**0.00**	**88.00**	
Heterogeneity in community livestock	Nonadopters	199	0.50	2467.76	11440.67
	Adopters	**49**	**2.00**	**13381.69**	**42451.97**
Percentage of rules made in collaboration with chief and organization 2000	Nonadopters	200	0.00	0.90	1.67
	Adopters	**50**	**0.00**	**1.81**	**3.99**
Village dominant in clay soil	Nonadopters	200	0.00	17.50	
	Adopters	**50**	**0.00**	**28.00**	
Village dominant in poor degraded soil	Nonadopters	200	0.00	40.50	
	Adopters	**50**	**0.00**	**34.00**	
Percentage of households land in poor degraded soil	Nonadopters	198	1.00	0.25	0.36
	Adopters	**49**	**2.00**	**0.29**	**0.37**
Percentage of households land in sandy soil	Nonadopters	198	1.00	0.53	0.42
	Adopters	**49**	**2.00**	**0.45**	**0.41**
Field under fallow 2002	Nonadopters	200	0.00	28.50	
	Adopters	**50**	**0.00**	**34.00**	
Low rainfall, dry oudalan	Nonadopters	200	0.00	45.00	
	Adopters	**50**	**0.00**	**24.00**	
Medium rainfall, north seno	Nonadopters	200	0.00	23.50	
	Adopters	**50**	**0.00**	**28.00**	
Income variance in 2000	Nonadopters	200	0.00	1.64e+11	1.93e+11
	Adopters	**50**	**0.00**	**1.58e+11**	**1.55e+11**

23 The first row records results concerning nonadopters, whereas the second row is about adopters of stone bund techniques.

Table A3: Descriptive statistics (Migrant/Nonmigrant)[24]

Variable	Migration strategy	N	Percent missing	Mean	Standard Deviation
Price and transaction costs					
Distance to regional capital	Nonmigrants	135	0.00	34.96	20.81
	Migrants	**115**	**0.00**	**34.30**	**18.48**
Distance to the market	Nonmigrants	134	0.74	16.05	10.92
	Migrants	**114**	**0.87**	**19.42**	**9.64**
Shifters in consumption and farm production					
Dummy, non-member remitted	Nonmigrants	135	0.00	0.00	0.00
money and/or inkind	**Migrants**	**115**	**0.00**	**0.16**	**0.36**
Available labor force 2002	Nonmigrants	135	0.00	5.71	2.77
	Migrants	**115**	**0.00**	**7.28**	**3.85**
Ethnic group	Nonmigrants	135	0.00	9.30	5.78
	Migrants	**115**	**0.00**	**9.77**	**6.17**
Formal cooperation 2000	Nonmigrants	134	0.74	0.23	0.18
	Migrants	**114**	**0.87**	**0.23**	**0.15**
Effective cooperation 2000	Nonmigrants	134	0.74	0.65	0.25
	Migrants	**114**	**0.87**	**0.67**	**0.19**
Average age of household	Nonmigrants	135	0.00	37.14	7.75
	Migrants	**115**	**0.00**	**33.72**	**5.87**
Dummy public school or literacy	Nonmigrants	135	0.00	9.63	
	Migrants	**115**	**0.00**	**26.96**	
Density household	Nonmigrants	135	0.00	0.04	0.03
	Migrants	**115**	**0.00**	**0.05**	**0.05**
External project innovation	Nonmigrants	135	0.00	16.30	
support	**Migrants**	**115**	**0.00**	**15.65**	
Number of quarters	Nonmigrants	135	0.00	5.10	3.18
	Migrants	**115**	**0.00**	**4.99**	**2.77**
Total number of plots per	Nonmigrants	135	0.00	2.16	1.33
household	**Migrants**	**115**	**0.00**	**2.50**	**1.35**

24 The first row records results concerning nonmigrants, whereas the second row is about migrants.

Table A3: Descriptive statistics (Migrant/Nonmigrant)[25] (continued)

Variable	Migration strategy	N	Percent missing	Mean	Standard Deviation
Total number of contour stone bund	Nonmigrants	135	0.00	0.29	0.77
	Migrants	**115**	**0.00**	**0.30**	**0.76**
Market participation, soil quality and risk variables					
Food buyer	Nonmigrants	135	0.00	93.33	
	Migrants	**115**	**0.00**	**98.26**	
Heterogeneity in community livestock	Nonmigrants	134	0.74	7116.35	29194.95
	Migrants	**114**	**0.87**	**1694.69**	**4133.89**
Percentage of rules made in collaboration with chief and organization 2000	Nonmigrants	135	0.00	0.88	2.34
	Migrants	**115**	**0.00**	**1.31**	**2.33**
Village dominant in clay soil	Nonmigrants	135	0.00	27.41	
	Migrants	**115**	**0.00**	**10.43**	
Village dominant in poor degraded soil	Nonmigrants	135	0.00	34.81	
	Migrants	**115**	**0.00**	**44.35**	
Percentage of households land in poor degraded soil	Nonmigrants	134	0.74	0.24	0.35
	Migrants	**113**	**1.74**	**0.27**	**0.37**
Percentage of households land in sandy soil	Nonmigrants	134	0.74	0.45	0.43
	Migrants	**113**	**1.74**	**0.58**	**0.40**
Field under fallow 2002	Nonmigrants	135	0.00	30.37	
	Migrants	**115**	**0.00**	**28.70**	
Low rainfall, dry oudalan	Nonmigrants	135	0.00	28.89	
	Migrants	**115**	**0.00**	**54.78**	
Medium rainfall, north seno	Nonmigrants	135	0.00	22.22	
	Migrants	**115**	**0.00**	**26.96**	
Income variance in 2000	Nonmigrants	135	0.00	1.23e+11	1.50e+11
	Migrants	**115**	**0.00**	**2.10e+11**	**2.13e+11**

25 The first row records results concerning nonmigrants, whereas the second row is about migrants.

A2 Additional Regressions

Table A4: Probit with Sample Selection: Migration and Adoption

	(1) Adoption of stone bunds	(2) Migrant household
Number of quarters	-0.071	0.013
	(-1.39)	(0.36)
Average age of household	-0.002	-0.038
	(-0.07)	(-2.76)***
Available labor force 2002	0.025	0.103
	(0.52)	(2.73)***
Food buyer	-5.782	0.784
	(-0.00)	(1.61)
Low rainfall, dry oudalan	-0.803	1.261
	(-2.19)**	(4.74)***
Medium rainfall, north seno	-0.744	0.743
	(-2.07)**	(2.86)***
Income variance in 2000	-1.06e-12	1.32e-12
	(-1.59)	(2.25)**
Dummy public school or literacy	-0.077	0.488
	(-0.21)	(1.81)*
Density household		8.612
		(2.94)***
Ethnic group		0.044
		(2.66)***
% of rules under chief and organization 2000		-0.017
		(-0.38)
Total number of plots per household		-0.121
		(-1.46)
Constant	6.728	-1.726
	(0.00)	(-2.10)**
Observations	250	250

z statistics in parentheses
* Significant at 10%; ** significant at 5%; *** significant at 1%
LR test of indep. eqns. (rho = 0): chi2(1) = 2.55 Prob > chi2 = 0.1100

The test rejected the assumption of sample selection bias and gives further support to the treatment model approach with bootstrapping.

Table A5: Test of endogeneity of buyer strategy in migration decision

	(1) Food buyer	(2) Migrant household
Distance to the market	-0.002	
	(-1.84)*	
Heterogeneity in community livestock	-0.000	
	(-1.71)*	
Number of quarters	0.007	0.028
	(1.44)	(0.72)
Average age of household	-0.002	-0.042
	(-1.13)	(-2.78)***
Available labor force 2002	-0.005	0.063
	(-1.20)	(1.88)*
Low rainfall, dry oudalan	0.082	1.469
	(2.34)**	(4.09)***
Medium rainfall, north seno	0.030	0.658
	(0.81)	(2.63)***
Density household	0.004	9.058
	(0.01)	(3.43)***
Ethnic group	-0.000	0.033
	(-0.06)	(1.84)*
Income variance in 2000	-0.000	0.000
	(-0.06)	(2.12)**
Dummy public school or literacy	-0.012	0.504
	(-0.35)	(1.98)**
Food buyer		-2.077
		(-0.69)
Residuals		2.742
		(0.90)
Constant	1.038	1.080
	(12.03)***	(0.35)
Observations	248	248
R-squared	0.07	0.24

Z statistics in parentheses
* Significant at 10%; ** significant at 5%; *** significant at 1%

Excluded instruments: distance to the market, heterogeneity in community livestock
Wald tests for significance Residuals: Prob > chi2: 0.37

Table A6: IV migration decision and Overidentification test

	Migrant household
Food buyer	-0.693
	(-0.74)
Number of quarters	0.006
	(-0.47)
Average age of household	-0.012
	(-2.50)**
Available labor force 2002	0.017
	(1.65)*
Low rainfall, dry oudalan	0.450
	(4.07)***
Medium rainfall, north seno	0.199
	(2.41)**
Density household	2.787
	(3.47)***
Ethnic group	0.010
	(1.69)*
Income variance in 2000	0.000
	(2.33)**
Dummy public school or literacy	0.163
	(1.99)**
Constant	0.851
	(0.89)
Observations	248
R-squared	0.18

Notes:
Z statistics in parentheses
* Significant at 10%; ** significant at 5%; *** significant at 1%
Overidentification test of buyer strategy:
Instrumented variable: food buyer.
Instruments are: distance to the market, heterogeneity in community livestock.

Tests of overidentifying restrictions:
Sargan N*R-sq test 1.588 Chi-sq(1) P-value = 0.2076
Basmann test 1.521 Chi-sq(1) P-value = 0.2174