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Climate Variability, Temporal Migration, and Household Welfare among Agricultural Households in Tanzania

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Abstract: Climate change has been one of the factors inducing people to migrate internally. As a result of climate change risks, the temporal migration strategy has been employed as an insurance strategy to cope with its impacts. This study analyses whether climate variability is a driving factor for temporal migration among agricultural households and whether such migration shields farmers from agricultural shocks. The study used three waves of the Tanzania National Panel Survey data and employed various descriptive and panel-data econometric techniques in the analyses. Results indicated that climate variability has no effect on overall agricultural production but has a significant effect on maize production, a staple food crop in Tanzania. Moreover, high market value from production was associated with a lower chance that climate variability forced a household member to migrate. In cases where climate change leads to temporal migration, the migrants may shield the household from large welfare losses by bringing back their earned income with new skills. More investments in adaptation to climate change can reduce temporal migration. This will facilitate retaining productive forces, thus boosting the rural economy where agriculture is commonly practiced.

Keywords: climate variability; migration; welfare; agricultural households; panel data models

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1. Introduction

Climate change is one topic of global concern, and its effects on global and regional economic systems and welfare are vivid. There are already observed increasing temperatures, changing precipitation patterns, and a greater frequency of some extreme events, such as floods and droughts, which affect economic activities [1,2]. The effects of climate change are variable across countries and sectors of the economy, but poor countries and the agriculture sector have been and will be substantially affected, leading to welfare losses, especially for agricultural households. Climate change is a matter of policy concern for Africa, given that about 15% of the GDP and two-thirds of employment come from agriculture, which is mostly rain-fed [3].

In Tanzania, the agriculture sector has contributed about 28% of the GDP, 24% of exports, and about 65% of total employment during the period between 2016 and 2017 and 2020 and 2021 [4]. During that period, the agriculture sector grew at an average rate of 5.1% per year, lagging behind the nation's target of 7.6% per year [4]. The sector plays an important role in national food security and industrial sector development by providing raw materials. However, the agriculture sector faces multiple threats, among them the declining production of different crops caused by climatic variability and unpredictability. The increasing adverse effects of climate change are also felt in other sectors of the economy and pose a threat to human welfare. Therefore, climate change and climate variability are an important source of risk for rural households in Africa generally and Tanzania in particular [5]. Reducing the vulnerability of the agricultural sector to climate change can significantly contribute to socio-economic development and ensure food security in Africa.

The range of mechanisms employed by households to insure against risks has been documented in the literature, including income smoothing, income diversification [6], selling productive assets like land [7], investing in low-risk but low-return investment [8], and inter-household family transfers [9]. For low-income households that cannot afford formal insurance, informal insurance through social networks is also common; however, these networks tend to be fragile and not sustain everyone's interests [10]. Most of these mechanisms work better for idiosyncratic risks, which are micro- or individual-specific, but not effective for covariant risks where the whole community experiences the same climatic stress. In the context of covariant risks, such as climate risk, the spatial diversification of income through migration may be adopted as an option to minimize the vulnerability of farmers to climate and weather risks [5,11].

Spatial diversification has been employed as a mechanism to ensure against covariant risks like climate risk. Each year about 20 million people leave their homes for different areas in their countries, and others migrate internationally as a result of natural hazards, such as prolonged droughts, abnormally heavy rains, sea level rise, and cyclones [12]. Temporal migration may guarantee vulnerable households by supplementing income from remittances, extended business networks, or benefits from returning migrants who have acquired capital and skills. A household that can afford migration costs may choose to relocate some of its members to other parts of the country so as to reduce the correlation between household location and income shocks [9]. However, benefits only materialize if migrants remain in contact with their sending household. So, the household decisions on who migrates, who remains in the original location, and the extent of inter-household family transfers or returning back are important.

The mechanism, effectiveness, and limitations of temporal migration as an insurance strategy is an empirical question for the researcher. Previous studies have analyzed the links between climate risk, internal migration, agricultural productivity, and income [5,13–16]. However, not much has been done to analyse intra-household decisions on who migrates and the mechanisms through which those who migrate generate income and transfer income back to the original households. This study, therefore, aimed to examine the decision and extent to which households engaged in temporal migration to shield themselves against agricultural risk due to climate-related shocks and how this affected the welfare of the households. Specifically, the study had four objectives: to assess and compare the rate of temporal migration by households' main economic activity; to examine the characteristics of household members who migrate due to climate variability; to analyze the effect of climate variability on temporal migration among agricultural households; to examine the effects of temporal migration due to climate variability on household welfare and the mechanisms driving those effects.

The rest of the paper is organized as follows: Section 2 reviews previous literature, presents the theoretical framework, and provides the conceptual framework; Section 3 describes the materials and methods used; Section 4 presents the results from the analyses and interprets; Section 5 discusses results; Section 6 provides the conclusions and policy implications.

2. Literature Review and Theoretical Framework

Agriculture is a sector that is predominantly climate-sensitive, given its interactions with the environment and over-dependency on rain, especially in developing countries. Several studies [17–20] have documented economic consequences such as low productivity, unemployment, lack of opportunities for advancement, and natural disasters as a result of climate change. Literature has analyzed the use of migration as a response to climate variability in both developing countries [21–24] and developed countries [25]. Several theories have been put forward to explain the relationship between climate variability, migration, and household welfare.

The most prominent theory explaining the link between climate variability and migration is the "push and pull" theory. Push factors prompt people to leave their original location and settle elsewhere, while pull factors attract migrants to new areas. Adverse conditions caused by climate change (such as lower rainfall) typically involve an increase in the "push" forces (such as reduced agricultural production), which leads to temporary or permanent migration [26]. People migrate temporarily or permanently to either avoid or recover from adverse climatic events. They migrate internally within countries on a temporary or a more permanent basis to seek new livelihood opportunities; they move temporarily or permanently to other countries to achieve the same desires. Climate could also be a pull factor from the destination (for example, more economic opportunities in areas with a conducive climate) [16]. Bardsley and Hugo [26] put forward three main processes through which climate change impacts are likely to manifest themselves as push factors on migration patterns: The first is increasing experiences of the risk of environmental hazards and associated socio-ecological events; second is the changing resource condition trends through time that alter access and effective utilization of natural resources; and third is the perception of the risk of the impacts of climate change, irrespective of real experience.

Another relevant theory is the cost-benefit theory. This simple economic model suggests that economic agents that make a decision on migration evaluate the costs and benefits of moving to a potential destination location against the costs and benefits of remaining in their current location [16,27]. A person will migrate if the movement to another location provides a greater net benefit over the period under decision. The effects of climate on migration in such a model can be seen through changes in economic opportunities or through changes in climate amenities [28]. Climate variability in both origin and destination areas affects the direction, magnitude, and duration of migration flows, with more in-flows towards areas with a more favourable climate. This implies that, in some cases, the optimal choice could be a temporal rather than permanent migration.

The specific-factor model also explains the link between climate, migration, and welfare. Barrios et al. [29] used a specific-factor model to construct a theoretical framework that conceptualized the link between climate, migration, and welfare. The framework assumed an economy with two sectors, agriculture or rural and manufacturing or urban, and three factors of production, "effective" land input, labour, and capital. The land was specific to the agricultural sector, whereas capital was specific to the manufacturing sector, and labor freely moved between the two sectors. The effective land input in production depended on climate. Changes in the climate affected agricultural production through changes in the productivity of land (the input specific to agriculture). Poor climatic conditions will adversely affect the agriculture or rural sector and force labour to shift to the manufacturing or urban sector, leading to migration and poor welfare among agricultural or rural households.

These theories are not mutually exclusive but rather interconnected to build a conceptual framework for the relationships between climate variability, migration, and household welfare. Climate variability links with migration through displacement caused by extreme events such as floods or droughts. However, climate change interacts with other social, economic, and environmental drivers of migration, which reinforce the effects of climate change [30,31]. For agricultural households, the main effect of climate change will be on agricultural productivity and risk that could impact household food security and welfare. Climate variability is expected to degrade the quality of farmland through increased erosion or salination, which will, in turn, diminish the size, suitability, and productivity of farmland [32]. Climate variability may also cause deterioration in the quality and availability of natural resources, including forests, water, and other productive ecosystems, and lead to a reduction in agricultural yield [33]. A decrease in agricultural productivity may eventually push agricultural households (or some members) to migrate.

Climate variability may happen in the form of changing agricultural seasons, increased temperature and rainfall variability, and frequent extreme events (such as floods and droughts). This, in turn, increases production risk, especially when agriculture is mainly dependent on climate, which induces migration [34–36]. Thus, climate change risks increase the number of individuals who engage in short-term rural–rural migration [37–39]. Due to the decline in agricultural productivity and increases in production risk, farmers may resort to using family labour which depresses rural wages, mounting pressure, especially for youth, to migrate to urban areas [40].

Other studies have classified the channels through which climate change can affect rural migration into two categories: the indirect channel of effects on incomes and conflicts [5,41]. The decision to migrate can be affected by the household's perceptions of climate change, while the socio-economic characteristic of farm households determines how vulnerable the household is to climate-induced shocks [39]. Reduced agricultural productivity due to climate change describes decreasing incomes among farmers whose livelihood depends on agriculture. As a result, farmers may see the need to migrate to favourable areas to improve their incomes [5]. Climate change may also bring potential conflicts on constrained economic resources, which may be a factor for others to migrate [41].

A study by Scheffran [38] analysed the relationship between migration and climate change adaptation in three ways. First, migration was used as an adaptation for preventing forced migration. Migration can be used as a mechanism to avoid forced migration in the aftermath of climate-induced destruction of livelihoods. Second, migration was used as an adaptation mechanism to climate change. In that way, migration could be considered a mechanism to reduce population pressure and pressure on scarce resources. Migration also sent away some household members to search for opportunities to diversify income, gain new knowledge, spread risk, and accumulate assets that could shield the household from future calamities. The third was the use of migration for adaptation. Migrants in host regions that already have secure opportunities, resources, and networks can help their families in the region of origin to diversify household livelihoods and support climate adaptation among others, which will somewhat compensate for the initial destruction in livelihood in the form of transfers.

The decision on whether to migrate is not an individual decision but rather a group decision (such as a household). However, a person who is young, better educated, less risk-averse, and well-connected to people in destination areas is more likely to migrate than the general population in the region of out-migration [42]. A study by Msigwa and Mbongo [18] on the determinant of internal migration in Tanzania found that demographic characteristics such as gender, age, marital status, level of education, skill level, household size, and income significantly determined migration. Climate-induced migration is contextual, for instance, depending on the agro-ecological conditions or cultural norms, as in the case of women's migration [43]; this may lead to different studies producing different results. The cultural norms of the location may also influence the role of women's migration [43] and are usually related to marriage [5]. Therefore, understanding and characterizing the nature of migration due to climate variability is prime to understanding the mechanism of its effect.

3. Material and Methods

3.1. Data

The study used the three waves of the Tanzania National Panel Survey data (TNPS) (2008–2009, 2010–2011, and 2012–2013), which is part of the Living Standard Measurement Studies collected by the World Bank and the Tanzania National Bureau of Statistics. The first wave was conducted over twelve months, from October 2008 to September 2009; the second wave ran from October 2010 to September 2011; and similarly, the fieldwork for the third wave of NPS was from October 2012 to September 2013. During the second and third waves, specialized tracking teams remained in the field until the month of November.

The original sample size of the first wave was 16,709 individuals from 3265 households, and it was designed to be representative of the national, urban or rural, and major agro-ecological zones. The total sample size of households was clustered in 409 enumeration areas (of which 2063 households were in rural areas and 1202 in urban areas) across mainland Tanzania and Zanzibar [44]. For the second wave of the NPS, the total sample size was 20,559 individuals from 3924 households. This represented 3168 households in the first wave and 659 split-off households, which translated to an attrition rate of 3%. The third wave consisted of a sample size of 25,412 individuals from 5015 households, which represented the re-interviewed households, split-off households and those that were not located and interviewed during the second wave. A total of 3786 households out of the targeted 3924 households were relocated and re-interviewed, translating to an attrition rate of roughly 3.5 percent between the second and third wave (see [44,45] for more details).

3.2. Variables

The key variables used in this analysis are defined below.

The temporal migrant was measured in two ways. The first, as a binary variable at the household level, took a value equal to one if at least one member of a household was away from one to nine cumulative months from the household and zero otherwise. It was also measured as a binary variable at the individual level if an individual migrated temporarily following the definition above. The second, as a continuous variable at the individual level that indicated the number of cumulative months an individual had been temporarily away from the household.

Climate variability was measured as a deviation of temperature and rainfall from the average rainfall in the location from the past 50 and 10 years. The deviations from the previous year's recorded levels of rainfall were also used in the analysis but not reported in the main results. Temperature and rainfall data were provided in the TNPS data.

Welfare was measured as the total per capita expenditure of the households and by the number of remittances received from the household's migrants.

TNPS contained a lot of information that provided a range of household characteristics, such as household size, education level, assets holdings, distance to the nearest major road, distance to the district capital, and agricultural information on land size, ownership, and crop production. We used this data in different estimation equations.

3.3. Empirical Model

The study employed two analytical approaches: descriptive and econometric analyses. Descriptive analysis is performed by exploring the measures of central tendency and dispersion of the individual key variables as well as the trends. Then, bi-variate relationships are analysed using cross-tabulations. The aim of descriptive analysis is to provide the overall picture that guides the econometric analysis, provide a ground for interpreting and discussing econometric results, and explain the mechanisms driving the results. The first objective, which aimed to assess and compare the rate of temporal migration by households' main economic activity, was performed using descriptive statics.

The second objective, which examined the characteristics of household members who migrate, was analysed at the individual level. The outcome variable was either a dummy variable (=1 if an individual member of the household migrated) or continuous (the number of cumulative months an individual had been temporarily away from the household) using pooled cross-sectional data. In all the cases, we estimated a model with the generic form:

$$TM_{it} = \alpha + X_{it}\beta + \varepsilon_{it} \tag{1}$$

where subscript i is the index for the individual and t is the time index. TM_{it} is a dummy or continuous measure of individual migration; X_{it} is a set of individual characteristics such as age, sex, level of education, whether an individual was head of household, and occupation; and ε_{it} is the error term.

The third objective aimed to analyse the effects of climate variability on temporal migration among agricultural households. We assumed that climate variability had a direct effect on migration decisions and that its effect may be reinforced by agriculture production. Therefore, an estimation model with level and interaction terms for climate variability and agriculture production variables was employed to estimate the factors affecting the household decision to send at least one migrant.

$$TM_{jt} = \alpha + \beta Y_{jt} + \gamma CV_{jt} + \rho\left(Y_{jt} * CV_{jt}\right) + H_{jt}\delta + \varepsilon_{jt} \tag{2}$$

where subscript j is the index for a household and t is the time index; TM_{jt} is a dummy for whether a household had at least one temporal migrant; Y_{jt} is the agricultural production prior to migration; H_{jt} is a set of pre-migration characteristics of a household; and ε_{jt} is the error term.

The fourth objective aimed to examine the effects of temporal migration due to climate variability on household welfare and the mechanisms driving those effects. In this case, the outcome variables were remittances and household expenditure. It was estimated using a fixed effect model.

$$HE_{jt} = \alpha + \beta TM_{jt} + \delta H_{jt} + \varepsilon_{jt} \quad (3)$$

where HE_{jt} is a household's per capita expenditure or the number of remittances received by a household.

We took advantage of the panel data. We had to estimate panel data models. Estimating the above equations using OLS faced a challenge when the explanatory variables were correlated with unobservable characteristics because OLS yields are biased and inconsistent estimators. One approach was to eliminate the unobserved heterogeneity in the application of the fixed effects (FE) model. The model transformed the variables by time-demeaning, which is the process leading to the elimination of the time-invariant variables, including the unobserved heterogeneity. The process was referred to as the effects- or within-transformation. Then a pooled OLS estimation was applied to the transformed variables. This estimator, however, swept away the coefficients of the time-invariant observable variables since they disappeared through the within-transformation. If the time-varying variables were of more interest in the analysis of the model, the FE estimator yielded more robust parameter estimates [46]. If it was believed that individual heterogeneity was uncorrelated with the explanatory variables, then the fixed effect model was inefficient but still consistent. In such a case, the random effects (RE) model, which exploited the serial correlation in the idiosyncratic error term in a generalized least-square framework, produced more efficient parameter estimates. However, both approaches did not solve the problem of endogeneity emanating from time-variant individual heterogeneity. Thus our results should be interpreted with that caveat.

4. Results

This section presents results for all the objectives from the analysis of data.

4.1. Descriptive Analysis of Temporal Migration at the Household Level

We started by presenting the descriptive analyses. Table 1 shows the rate of individual migration by sex and age. Results indicated that overall the men members of households had a slightly higher rate of migration compared to the women. The rates of migration were higher among the working population aged 15–64 years. There was, however, a difference in the migration rates between men and women within the working population, with more women aged 15–17 years migrating compared with men and more men than women of age 18–64 years migrating.

Table 1. Rate of individual migration by sex and age for the three waves (%).

		2008/09			**2010/11**			**2012/13**		
		Female	**Male**	**Total**	**Female**	**Male**	**Total**	**Female**	**Male**	**Total**
Age group	5–14 years	2.26	2.57	2.41	2.94	2.14	2.55	2.59	2.6	2.59
	15–17 years	8.79	6.05	7.42	10.98	7.97	9.5	12.53	8.4	10.54
	18–64 years	5.63	6.79	6.17	5.54	6.48	5.98	6.16	7.16	6.64
	65+ years	2.96	2.96	2.96	1.42	2	1.68	2.82	1.88	2.41
	Total	4.68	5.1	4.88	4.99	5.01	5	5.45	5.61	5.53

No more information from the dataset was collected for those who stayed away from the household for more than 9 months. For those who migrated but stayed in the household for at least 3 months, more information was available. Among those who migrated temporarily, the rate was higher among those who were students, followed by those who did not have jobs, while the rate was relatively low among those whose main occupation was in agriculture among all three waves, as shown in Table 2.

Table 2. The rate of migration by occupation for the three waves (%).

Occupation	2008/09	2010/11	2012/13
No job	3.34	5.7	5.85
Agriculture	1.54	2.57	2.9
Resource extraction	0	3	5.11
Government employee	2.11	5.42	5.33
Private employee	3.36	6.3	7.08
Self-employed	3.11	1.88	3.69
Family worker	1.66	4.97	7.34
Student	15.95	19.84	23.89
Total	3.2	4.91	5.7

Further, the rate of migration was higher among those without any economic activity, followed by those with wage employment, as indicated in Table 3.

Table 3. The rate of migration by main economic activity for the three waves (%).

Economic Activity	2008/09	2010/11	2012/13
None	6.93	10.99	12.99
Wage job	2.35	5.31	6.11
Self-employment	2.02	2.13	3.33
Wage- and self-employment	1.56	2.03	4.82
Self-agriculture only	1.99	3.27	3.62
Total	3.2	4.89	5.7

4.2. Factors Associated with Members Who Migrate from Households

To ascertain whether the differences in attributes observed between migrants and non-migrants were statistically significant, we estimated a simple probit model for a binary variable for migration and OLS for the number of months an individual had been away from the household. Results are presented in Table 4 below.

Table 4. Factors associated with migration and duration of migration (coefficients).

	(1)	(2)	(3)	(4)	(5)	(6)
	2008/09		2010/11		2012/13	
VARIABLES	Migrated	Migration Duration	Migrated	Migration Duration	Migrated	Migration Duration
	Probit	OLS	Probit	OLS	Probit	OLS
Age	0.00995	0.00617	−0.000781	0.00219	−0.00454	−0.00192
	(0.0106)	(0.00556)	(0.00754)	(0.00605)	(0.00623)	(0.0055)
Age square	−0.000172	−0.0000571	−0.000067	−0.000051	−0.000049	−0.000037
	(0.000130)	(0.00006)	(0.00009)	(0.00007)	(0.00007)	(0.00006)
Relationship to head of household (base = head)						
Spouse	0.0154	0.0379	−0.00882	−0.00991	−0.112 *	−0.130 **
	(0.111)	(0.0555)	(0.0810)	(0.0635)	(0.0666)	(0.0594)
Son/daughter	0.475 ***	0.319 ***	0.283 ***	0.302 ***	0.174 ***	0.209 ***
	(0.108)	(0.0645)	(0.0793)	(0.0703)	(0.0642)	(0.0643)

Table 4. *Cont.*

	(1)	(2)	(3)	(4)	(5)	(6)
	2008/09		2010/11		2012/13	
VARIABLES	**Migrated**	**Migration Duration**	**Migrated**	**Migration Duration**	**Migrated**	**Migration Duration**
	Probit	**OLS**	**Probit**	**OLS**	**Probit**	**OLS**
Stepson/daughter	0.202	0.0541	0.0824	−0.0314	−0.0460	−0.126
	(0.258)	(0.152)	(0.162)	(0.151)	(0.133)	(0.138)
Sister/brother	0.583 ***	0.348 **	0.319 **	0.376 ***	0.326 ***	0.592 ***
	(0.187)	(0.140)	(0.130)	(0.133)	(0.0993)	(0.116)
Grandchild	0.152	0.0847	0.177	0.159	0.0581	0.0598
	(0.173)	(0.0987)	(0.113)	(0.106)	(0.0930)	(0.0970)
Mother/father	0.815 ***	0.449 ***	0.557 **	0.364 **	0.531 ***	0.355 **
	(0.286)	(0.155)	(0.226)	(0.174)	(0.186)	(0.168)
Other relatives	0.659 ***	0.563 ***	0.452 ***	0.661 ***	0.265 ***	0.391 ***
	(0.114)	(0.0758)	(0.0864)	(0.0840)	(0.0742)	(0.0793)
Live-in servant	0.892 ***	1.089 ***	1.198 ***	2.610 ***	1.030 ***	2.101 ***
	(0.227)	(0.190)	(0.146)	(0.201)	(0.130)	(0.194)
Other non-relatives	0.418	0.312	0.674 ***	0.898 ***	0.544 ***	0.836 ***
	(0.332)	(0.226)	(0.157)	(0.188)	(0.133)	(0.170)
Sex (Male = 1)	0.0769	0.0756 **	0.00606	0.00709	−0.0442	−0.0599
	(0.0594)	(0.0385)	(0.0445)	(0.0431)	(0.0382)	(0.0407)
Living in birth district	−0.259 ***	−0.231 ***	−0.117 ***	−0.213 ***	−0.0840 **	−0.132 ***
	(0.0590)	(0.0362)	(0.0436)	(0.0396)	(0.0371)	(0.0368)
Schooling (years)	0.0771 ***	0.0623 ***	0.0568 ***	0.0641 ***	0.0538 ***	0.0659 ***
	(0.00903)	(0.00512)	(0.00623)	(0.00551)	(0.00519)	(0.00506)
Economic activity (base = agriculture)						
No economic activity	0.0712	0.0512	0.174 ***	0.185 ***	0.311 ***	0.372 ***
	(0.0722)	(0.0441)	(0.0526)	(0.0503)	(0.0452)	(0.0483)
Wage employment	−0.182 *	−0.0979 *	0.0759	0.0836	0.114 **	0.0896 *
	(0.102)	(0.0553)	(0.0611)	(0.0548)	(0.0517)	(0.0504)
Self-employment	−0.0803	−0.101 *	−0.137 *	−0.115 *	−0.0545	−0.0761
	(0.102)	(0.0544)	(0.0780)	(0.0594)	(0.0595)	(0.0527)
Wage and self-employ	−0.192	−0.0877	−0.274 *	−0.178	0.0993	0.0679
	(0.218)	(0.107)	(0.155)	(0.109)	(0.0910)	(0.0905)
Constant	−2.683 ***	−0.105	−2.148 ***	0.185	−1.946 ***	0.356 ***
	(0.228)	(0.135)	(0.163)	(0.146)	(0.134)	(0.132)
Observations	10,476	10,476	13,316	13,314	16,572	16,570
R-squared		0.039		0.049		0.044

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

The results in Table 4 indicated that heads of households and their spouses have less probability of migrating compared with their children and other relatives within the household. This is intuitive since the heads of the household and their spouses were expected to stay, make decisions, and take care of the family. Other members of the family who are not in the nuclear family may also be seasonal migrants who migrated into a household and were likely to go back to their original households. The probability of migrating and duration of migration is also higher for those who do not live in the districts where they were born. The probability of migrating tends to be higher among those who have more years of education. Relative to those whose main activity is self-agriculture, those who have no economic activity have a higher likelihood of migrating.

4.3. The Effect of Climate Variability on Temporal Migration among Agricultural Households

We then analysed whether migration was associated with climate variability for agricultural households. We estimated the equations for the outcome variable that at least one of the household members migrated. The key variables capturing climate change were the long-term average temperature and rainfall (1960–1990) to benchmark the previous climatic conditions and the deviations of rainfall from the long-term 1960–1990 climate as well as the medium-term deviations of rainfall from the 2001–2009 average. Climate variability may indirectly influence migration through its effect on agricultural production. Thus, we included two variables that captured agricultural production: the value of the agricultural product produced in a year and the value of agricultural sales in a year. The climate and production variables entered the estimation equation in a level form and as interacted variables. Table 5 presents results for the effects of climate variability and agriculture production on the probability of a household having a temporal migrant from a fixed effect model estimation.

Table 5. The marginal effect of climate variability and agricultural production on a household having a temporal migrant (FE model).

VARIABLES	**(1) Household Has a Migrant**	**(2) Household Has a Migrant**	**(3) Household Has a Migrant**	**(4) Household Has a Migrant**
Log of the value of the agricultural harvest	0.00304		0.00111	
	(0.00193)		(0.00146)	
Prec. Dev. from 1960–1990	−0.118 *	−0.0428		
	(0.0609)	(0.0422)		
Log of the value of the agricultural harvest * Prec. Dev. from 1960–1990	0.00712			
	(0.00475)			
Log of the value of the agricultural sales		0.00117		0.00115
		(0.00128)		(0.00101)
Log of the value of the agricultural sales * Prec. Dev. from 1960–1990		0.000144		
		(0.00349)		
Prec. Dev. from 2001–2009			−0.0350	−0.0157
			(0.0614)	(0.0398)
Log of the value of the agricultural harvest * Prec. Dev. from 2001–2009			0.000876	
			(0.00541)	
Log of the value of agriculturalagricultural sales * Prec. Dev. from 2001–2009				−0.00152
				(0.00429)
Control variables	YES	YES	YES	YES
Observations	6529	6529	6529	6529
R-squared	0.005	0.004	0.004	0.004
Number of y1_hhid	2271	2271	2271	2271

Standard errors are in parentheses. * $p < 0.1$.

Results from Table 5 indicated that climate variability and agricultural production had no direct effect on the probability of a household sending a temporary migrant, nor did they reinforce each other to influence temporal migration.

This estimation considered agricultural production in its entirety. Households may be making decisions based on the major staple crops they produce; thus, we considered maize, which is the main staple food crop in Tanzania and is produced by the majority of rural households. In addition, focusing on one crop enabled us to include the yield, which proxied productivity in our estimation, which could not be calculated when all agricultural production was considered. Table 6 presents the results of the effects of climate variability and maize production on the probability of a household having a temporal migrant from a fixed effect model estimation.

Table 6. Marginal effects climate variability and maize production on temporal migration (FE model).

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the maize yield (kg/acre)	−0.0127		−0.00477	
	(0.00905)		(0.00701)	
Prec. Dev. from 1960–1990	0.112	0.510 **		
	(0.144)	(0.254)		
Log of the maize yield * Prec. Dev. from 1960–1990	−0.0320			
	(0.0257)			
Log of the value of maize yield (TZS/acre)		−0.0164 **		−0.00258
		(0.00824)		(0.00630)
Log of the value of the maize yield * Prec. Dev. From 1960–1990		−0.0516 **		
		(0.0228)		
Prec. Dev. From 2001–2009			0.254	0.685 *
			(0.208)	(0.371)
Log of the maize yield * Prec. Dev. from 2001–2009			−0.0519	
			(0.0371)	
Log of the value of the maize yield * Prec. Dev. from 2001–2009				−0.0646 *
				(0.0333)
Control variables	YES	YES	YES	YES
Region dummies	YES	YES	YES	YES
Observations	4405	4405	4405	4405
R-squared	0.017	0.018	0.017	0.017
Number of y1_hhid	1815	1815	1815	1815

Standard errors are in parentheses. ** $p < 0.05$, * $p < 0.1$.

It was found that climate variability, as measured by long-term deviation, increased the probability of a household sending a temporary migrant. The medium-term deviation, however, did not have a significant effect. The value of maize harvested per acre had a significant effect, but maize productivity had no significant effect on the probability of a household sending a temporary migrant. The higher the value of maize produced per acre, the lower the probability that a household would send a member as a migrant. This implied that low yield per se may not be a driving factor for sending a household member as a migrant if prices are good enough to restore the value of the produce. The interaction term of the value of maize produced per acre and long-term rainfall deviation was negative and significant, which meant that valuable production pared down the effect of climate variability on migration. Even if a household experienced climate variability, it had a lower probability of sending a migrant if the value of maize production per acre was good.

Next, we explored whether climate variability had an indirect effect on migration through its effects on agricultural productivity. We first analysed whether climate variability had a significant effect on the value of agricultural production and sales and then on maize yield and the value of maize yield for a limited sample of maize-producing households. The results, presented in Table 7, showed that, generally, climate variability did not statistically significantly affect agricultural production. So, the anticipated channel of the effect of climate variability on migration via agricultural productivity was not confirmed in this context. This may be because of climate adaptation; farmers might have adopted different farming techniques to absorb the effects of climate change.

Table 7. The marginal effect of climate variability on agricultural production (FE model).

PANEL A				
VARIABLES	(1) Log of the value of agricultural prod	(2) Log of the value of agricultural sales	(3) Log of the value of agricultural prod	(4) Log of the value of agricultural sales
Prec. Dev. from 1960–1990	−0.413	−0.334		
	(0.351)	(0.510)		
Prec. Dev. from 2001–2009			−0.588 **	−0.285
			(0.274)	(0.397)
Observations	6529	6529	6529	6529
R-squared	0.010	0.010	0.011	0.010
Number of y1_hhid	2271	2271	2271	2271
PANEL B				
VARIABLES	(1) Log of maize yield	(2) Log of value maize per acre	(3) Log of maize yield	(4) Log of value maize per acre
Prec. Dev. from 1960–1990	−0.193	0.209		
	(0.132)	(0.148)		
Prec. Dev. from 2001–2009			−0.0695	0.239 *
			(0.109)	(0.122)
	4405	4405	4405	4405
Observations	0.017	0.053	0.016	0.053
R-squared	1815	1815	1815	1815
Number of y1_hhid				

Standard errors are in parentheses. ** $p < 0.05$, * $p < 0.1$.

4.4. The Effect of Climate Temporal Migration on the Welfare of Agricultural Households

Lastly, the effect of temporal migration on household welfare was estimated. We estimated the effect of a household sending a temporary migrant on the household's per capita expenditure (in log form) and remittances (in log form). Then we interacted with the migration and remittance variables in another model to explore whether the two reinforced each other. Finally, we estimated whether remittances had an effect on a household's per capita expenditure.

Results for the marginal effects of temporal migration on household welfare are presented in Table 8. Temporal migration positively and directly affected household welfare rather than through remittances. This implied that temporal migrants might not be directly sending remittances to their homes. Rather they come back home with them and use it to improve their households' welfare. It could also imply that temporary migrants may have come back with new skills important for other farming and non-farming activities that increase household income, hence expenditure. The number of remittances itself positively and significantly affected the household expenditure obviously because, ceteris paribus, it increased household income.

To explore the effect of migration on welfare further, the migration variable interacted with climate variables. Table 9 presents the marginal effect of temporal migration on household welfare with climate change interaction variables. The results indicated that temporal migration and household welfare were positively associated. It also indicated that more deviation from long- and medium-term rainfall levels was positively correlated with higher per capita income. The interaction terms between climate and migration were insignificant except for migration and medium-term interaction effects on remittances implying that the two do not reinforce each other.

Table 8. The marginal effect of temporal migration on household welfare (FE model).

VARIABLES	(1) Log per Capita Expenditure	(2) Log Remittance	(3) Log per Capita Expenditure	(4) Log per Capita Expenditure
Hhd has a migrant	0.0838 ***	0.207	0.0445	
	(0.0229)	(0.277)	(0.0327)	
Ln remittance			0.0171 ***	0.0183 ***
			(0.00250)	(0.00231)
Hhd has a migrant * Log remittance			0.00785	
			(0.00685)	
Control Variables	YES	YES	YES	YES
Observations	6733	4507	4507	4507
R-squared	0.091	0.084	0.141	0.139
Number of y1_hhid	2271	2268	2268	2268

Standard errors are in parentheses. *** $p < 0.01$, * $p < 0.1$.

Table 9. The marginal effect of temporal migration on household welfare with climate change interaction variables (FE model).

VARIABLES	(1) Log per Capita Expenditure	(2) Log per Capita Expenditure	(3) Log Remittance	(4) Log Remittance
Hhd has a migrant	0.0652 **	0.0863 ***	−0.424	0.289
	(0.0298)	(0.0228)	(0.341)	(0.283)
Prec. Dev. from 1960–1990	0.372 ***		1.291 **	
	(0.0500)		(0.567)	
Prec. Dev. from 2001–2009		0.314 ***		0.735
		(0.0408)		(0.470)
Hhd has a migrant * Prec. Dev. from 1960–1990	−0.0980		−3.196 ***	
	(0.0881)		(0.995)	
Hhd has a migrant * Prec. Dev. from 2001–2009		−0.124		−1.796
		(0.122)		(1.370)
Control Variables	YES	YES	YES	YES
Observations	6716	6733	4490	4507
R-squared	0.103	0.103	0.09	0.085
Number of y1_hhid	2271	2271	2268	2268

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

Other estimations were conducted to check the robustness of the results. First, instead of using simple deviation, we used absolute deviations of rainfall in the medium- and long-term. Second, the deviations in rainfall from the previous year were used as the main short-term climate variable. Third, instead of annual precipitation, precipitation data during the wet season were used. Results remained characteristically similar to those presented and are presented in the Appendix A from Tables A1–A4.

5. Discussion

The results showed that the rate of temporal migration had been steadily increasing, and it is higher among the working population. By occupational categories, students had a higher proportion of migration, while agriculture was among those with a constantly lower proportion (but the absolute number is high). By the nature of the activity, those without jobs had a higher migration proportion. This implied that agriculture was not a pull factor as most youth without jobs migrated out of agricultural households, which could partly be explained by the vulnerability of agriculture to climate change, as it was found by Cameron [16]. In addition, within households, the heads and their spouses were less likely to migrate. This finding was similar to other previous studies in Tanzania, which have shown that with other factors being constant, those with closer family ties to the head are less likely to migrate [15,47].

The analysis of the effects of climate variability on temporal migration shows that climate variability, measured by deviations of the current level of rainfall, formed the long term (about 50 years) and medium term (about 10 years); the overall agriculture production did not have a significant effect on migration nor did it reinforce each other to influence temporal migration, similar to findings by Marchetta et al. [48] and Cameron [16]. The insignificant effect of climate variability on overall agricultural production could possibly be because farmers might have adopted different farming techniques to absorb the effects of climate change, as explained by Cameron [16].

This implies that "adaptation for preventing migration", for the time being, is the dominant pathway to prevent climate change from becoming a risk factor to household welfare that forces people to migrate, as explained by Scheffran et al. [38]. However, when zeroing in on households that produce maize, the major staple food in Tanzania, it was found that climate variability, as measured by the long-term deviation, increased the probability of temporal migration. The medium-term deviation, on the other hand, had insignificant effect. Climate change and variability may not necessarily be a push factor for temporal migrants in agricultural households unless it affected the staple food crop. This implied that when the core of the livelihood was threatened, the migration-for-adaptation pathway becomes important [38].

The value of maize harvested per acre had a significant effect on the probability of a household sending a temporary, but maize yield was insignificant. That means that a high market value from production was associated with a lower likelihood that climate variability led to migration. This finding signified that a low yield per se cannot fuel a household to send its member as a migrant if the prices are good enough to restore the value of the produce. Results had also shown that the effect of climate variability on migration was lower when a high market value was obtained from production.

Analysing the effect of temporal migration on household welfare indicated that households sending temporary migrants have a higher per capita expenditure compared to those without migrants. This effect was direct and not through sending of remittances. This finding implied that temporal migrants might not be directly sending remittances to their homes but rather are coming back home with their earned income, which boosts household expenditure, similar to findings by Scheffran et al. [38] and Jha et al. [39]. It also implied that temporary migrants had acquired new skills, which are employed to generate more income, hence expenditure.

6. Conclusions and Policy Implications

The link between climate variability and migration has been a topic of interest. The growing urgency to understand climate change and its effects on productivity and household welfare, especially for those living in climatic-prone areas and those whose livelihood depends on agricultural activities, is what motivates many studies in this area. The literature proposes several channels that can be used to analyse these links and how climate risks can be mitigated. Nonetheless, this study analysed whether seasonal, temporal migration is a channel that farmers use to respond to climate risk. The questions this study tried to answer were: Is the rate of temporal migration higher among agricultural households compared to other households? What are the characteristics of household members who migrate compared with those who remain in the original household location? If climate variability a driving factor for temporal migration among agricultural households? Does temporal migration improve household welfare? The study used data for agricultural households in Tanzania from three waves of the Tanzania National Panel Survey data (TNPS) (2008–2009, 2010–2011, and 2012–2013), which was part of the Living Standard Measurement Studies collected by the World Bank and the Tanzania National Bureau of Statistics.

Results showed that the rate of temporal migration has been steadily increasing and is higher among the working population age. However, the rate of migration is higher among those who are still pursuing education. Further results showed that most of those who migrate have no jobs, but they tend to have higher education. Within households, heads and their spouses are less likely to migrate. Findings also indicated that climate variability had no effect on overall agricultural production but had a significant effect on maize production, a staple food crop in Tanzania. A high market value from production was associated with a lower likelihood that climate variability would force a household member to migrate. It was also shown that climate variability had no significant effect on migration. In the case where climate change leads to temporal migration, the migrants may shield the household from large welfare loss by bringing back their earned income or coming back with new skills.

Our findings implied that climate change and variability may not necessarily be a push factor for temporal migrants in agricultural households but is important if it affects the staple food crop. This, in turn, implied that adaptation to climate change might reduce temporal migration, which is concentrated more in youth. The adoption of climate-smart agricultural practices by farmers will make agriculture less dependent on weather, reduce its vulnerability, and make it more resilient. This can be advantageous by making agriculture more attractive and retaining more youth in the sector, which can propel the rural economy where agriculture is mostly practiced. This role can be implemented by the government by putting in place a good business environment for agriculture. The private sector can also engage by supplying inputs, credits and middle-men services, and non-government players in creating awareness and supporting extension services.

In the case where climate change leads to temporal migration, the migrants may shield the household from large welfare loss by bringing back their earned income or coming back with new skills. This implies that strengthening non-farm enterprises where the income earned and skills acquired can be invested is an important strategy to reduce vulnerability to climate change among agricultural households. This can be implemented by local and central governments. On the other hand, areas affected by out-migration may become less productive and depopulated, which may affect their chances of being provided with public services creating economic disparities, while receiving areas may also experience social and economic challenges [30]. It is important, therefore, for policymakers to be aware of and direct the movement of migration.

The study was limited by a paucity of climate and agronomy data, such as the number of growing days and respective information on temperature, rainfall, and humidity. The use of recent data from waves four and five of the TNPS was also not possible because of a lack of geo-spatial data. Information on migration was also limited to those who migrated up to nine months in a year; no information was collected for those who stayed away from their household for more than that period. Given the limitations, the study estimated a static partial equilibrium model and, to a large extent, established correlation rather than causation. Future studies may seek to analyse the dynamic general equilibrium model and establish causality for the relationships that have been analysed.

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Appendix A

Table A1. Marginal effects climate variability and agriculture production on temporal migration (FE model): absolute deviations.

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the value of the agricultural harvest	0.00545 **		0.000690	
	(0.00252)		(0.00203)	
Abs_Prec. Dev. from 1960–1990	0.180 **	0.0722		
	(0.0755)	(0.0533)		
Log of the value of the agricultural harvest * Abs_Prec. Dev. from 1960–1990	−0.0139 **			
	(0.00575)			
Log of the value of agricultural sales		0.00268		0.00134
		(0.00171)		(0.00145)
Log of the value of agricultural sales * Abs_Prec. Dev. from 1960–1990		−0.00557		
		(0.00444)		
Abs_Prec. Dev. from 2001–2009			−0.00388	0.0417
			(0.115)	(0.0742)
Log of the value of the agricultural harvest * Abs_Prec. Dev. from 2001–2009			0.00323	
			(0.00995)	
Log of the value of agricultural sales * Abs_Prec. Dev. from 2001–2009				−0.00142
				(0.00773)
Control variables	YES	YES	YES	YES
Observations	6529	6529	6529	6529
R-squared	0.005	0.004	0.004	0.004
Number of y1_hhid	2271	2271	2271	2271

Robust standard errors are in parentheses. ** $p < 0.05$, * $p < 0.1$.

Table A2. Marginal effects climate variability and agriculture production on temporal migration (FE model): short term deviations.

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the value of the agricultural harvest	−0.000593		−0.00185	
	(0.00229)		(0.00275)	
Current Prec. Dev. from the previous year	−0.0360	−0.000615		
	(0.0722)	(0.0405)		

Table A2. *Cont.*

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the value of the agricultural harvest * Current Prec. Dev. from the previous year	0.00538			
	(0.00620)			
Log of the value of the agricultural sales		0.000846		−0.000911
		(0.00156)		(0.00185)
Log of the value of the agricultural sales * Current Prec. Dev. from the previous year		0.00307		
		(0.00443)		
Abs_Current Prec. Dev. from the previous year			0.0600	0.0315
			(0.1000)	(0.0546)
Log of the value of the agricultural harvest * Abs_Current Prec. Dev. from the previous year			0.00438	
			(0.00857)	
Log of the value of agricultural sales * Abs_Current Prec. Dev. from the previous year				0.00892
				(0.00584)
Control variables	YES	YES	YES	YES
Observations	4400	4400	4400	4400
R-squared	0.011	0.011	0.015	0.015
Number of y1_hhid	2267	2267	2267	2267

Robust standard errors are in parentheses. * $p < 0.1$

Table A3. Marginal effects climate variability and agriculture production on temporal migration (FE model): wet season precipitation.

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the value of the agricultural harvest	0.00218		0.00126	
	(0.00160)		(0.00151)	
Wet_Prec. Dev. from 1960–1990	−0.0930 *	−0.00673		
	(0.0484)	(0.0343)		
Log of the value of agricultural harvest * Wet_Prec. Dev. from 1960–1990	0.00663 *			
	(0.00370)			
Log of the value of the agricultural sales		0.00101		0.00101
		(0.00108)		(0.00104)
Log of the value of agricultural sales * Wet_Prec. Dev. from 1960–1990		−0.00155		
		(0.00282)		
Wet_Prec. Dev. from 2001–2009			−0.0493	0.0109
			(0.0671)	(0.0398)
Log of the value of agricultural harvest * Wet_ Prec. Dev. from 2001–2009			0.00239	
			(0.00572)	
Log of the value of agricultural sales * Wet_Prec. Dev. from 2001–2009				−0.00486
				(0.00411)
Control variables	YES	YES	YES	YES
Observations	6529	6529	6529	6529
R-squared	0.005	0.004	0.004	0.005
Number of y1_hhid	2271	2271	2271	2271

Robust standard errors are in parentheses. * $p < 0.1$.

Table A4. Marginal effects climate variability and agriculture production on temporal migration (FE model): wet season precipitation in the short term.

VARIABLES	(1) Household Has a Migrant	(2) Household Has a Migrant	(3) Household Has a Migrant	(4) Household Has a Migrant
Log of the value of the agricultural harvest	−0.000885		−0.00185	
	(0.00237)		(0.00275)	
Current Wet Prec. Dev. from the previous year	0.00627	−0.00483		
	(0.0439)	(0.0237)		
Log of the value of the agricultural harvest * Current Wet Prec. Dev. from the previous year	0.00126			
	(0.00386)			
Log of the value of the agricultural sales		0.000628		−0.000911
		(0.00154)		(0.00185)
Log of the value of the agricultural sales * Current Wet Prec. Dev. from the previous year		0.00315		
		(0.00280)		
Abs_Current Wet Prec. Dev. from the previous year			0.0600	0.0315
			(0.1000)	(0.0546)
Log of the value of the agricultural harvest * Abs_Current Wet Prec. Dev. from the previous year			0.00438	
			(0.00857)	
Log of the value of the agricultural harvest * Abs_Current Wet Prec. Dev. from the previous year				0.00892
				(0.00584)
Control variables	YES	YES	YES	YES
Observations	4400	4400	4400	4400
R-squared	0.011	0.011	0.015	0.015
Number of y1_hhid	2267	2267	2267	2267

Robust standard errors are in parentheses. * $p < 0.1$.

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