



Spatial Analysis of Climate Effect on Agriculture: Evidence from Smallholder Farmers in Côte d'Ivoire

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Abstract

Climate change has been affecting the agriculture sector over the past few decades. This impact could have serious consequences for farmers in developing countries. This paper applies the spatial approach to assess the response of agricultural net revenue to climate change in Côte d'Ivoire. It first uses a simple static comparative approach, to show that market imperfection induces spatial heterogeneity in agricultural product prices and hence spatial autocorrelation. Taking these findings as a point of departure, empirical analysis uses a Spatial Durbin Error Model based on 2016 World Bank Smallholder Household Survey

Data from Côte d'Ivoire. Results reveal that rainfall has a non-linear direct effect and positive linear spillover effects on agricultural net revenue. In addition, the paper shows that the total marginal effect of rainfall is positive in the central, eastern and northern regions of the country and negative in the coastal and western regions. Moreover, predictions indicate that a decrease in average precipitation of between 5% and 10% leads in general to a decrease in the average net agricultural income from about 0.45% to 1.38% while an increase in the same ranges leads to a decrease in the average net agricultural income from about 0.02% to 0.05%.

Introduction

Agriculture is an economic activity subject to various sources of risk (such as fluctuating markets, government policies, invasion of pests). Among these climate risk seems to be the most significant, according to literature from recent decades. Indeed, climate appears as a direct input to agricultural production which escapes the control of farmers. Any unforeseen variation in climate parameters likely leads to significant losses in agricultural production and therefore exacerbates the vulnerability of the poorest populations, especially in countries where agriculture is heavily dependent on rainfall.

For example, rainfall disturbances observed in Côte d'Ivoire since the 1960s have exposed Ivorian agriculture to many problems, including lower yields, loss of seeds, desertion of crops and modification of agricultural calendars (Dibi Kangah and Mian, 2016; N'da, 2016). Climate parameters, in particular rainfall and temperature, experience different variations between localities and over the years, partly due to climate change. The temperature rises gradually while the water supply decreases over the long term in response to climate change. The subsequent instability in agricultural production creates economic and social disruption in several regions of the country (Brou et al., 2005). Furthermore, forecasts indicate that future changes in temperature and precipitations will lead to changes in land and water regimes that will subsequently affect agricultural productivity in Côte d'Ivoire (Ahossane et al., 2013; Läderach et al., 2013). These production losses may have profound consequences for smallholder farmers for whom the vulnerability is particularly liable to be acute given technological and resource constraints. Their incomes are likely to experience significant variations. Therefore the analysis of the effects of climate change and/or climate variability on the incomes of smallholder farmers in Côte d'Ivoire requires special attention. Thus, our study aimed to analyse the effect of climate change on the incomes of smallholder farmers in Côte d'Ivoire.

From a general point of view, the concerns induced by climate change regarding the agriculture sector have given rise to several studies which have attempted to show the relationship between climate and agriculture in order to assess the effect

of climate variability or climate change on the sector. These studies generally fall into four categories: (i) the agronomic model (Rosenzweig, 1985); (ii) the traditional Ricardian model using cross-section data (Mendelsohn et al, 1994; Kurukulasuriya and Mendelsohn, (2008a); Wood and Mendelsohn, 2014; Khan et al. 2021); (iii) the Ricardian model with panel data qualified as “pseudo-Ricardian” (Deschênes and Greenstone, 2007; Baylie and Fogarassy, 2021); and (iv) controlled agricultural laboratory experiments which carefully isolate the effect of temperature and carbon dioxide (CO₂) on agricultural yields (Adams et al., 2001). In addition to these four groups defined in the literature, there is a new trend which uses the Ricardian model with the econometrics of spatial data (Dall'erba and Domínguez, 2016; Vaitkeviciute et al., 2019).

Most of the studies conducted in Africa use either the traditional Ricardian model or pseudo-Ricardian models. The studies generally show that climate change has non-linear and significant effects on net agricultural income per hectare with greater sensitivity to future increases in temperature (Jain, 2007; Kabubo-Mariara and Karanja, 2007; Ouedraogo, 2012). However, the Ricardian model has been the subject of many criticisms (Darwin, 1999; Polsky 2004; Schlenker et al., 2005, 2006; Deschênes and Greenstone, 2007), among which the price constancy hypothesis is recognized as a source of bias (Cline, 1996). This criticism constitutes a major gap in studies on African countries using this approach. Indeed, this hypothesis suggests that markets are perfect and therefore crop prices are spatially identical. This could not be realistic, especially for cross-sectional data on developing countries such as Côte d'Ivoire. In these countries, transaction and/or transportation costs act as a brake for the mobility of agricultural products so that price equilibrium after an imbalance in a given locality cannot be achieved instantly. What is more plausible is to assume that prices are balanced locally, within a small perimeter. The idea is that a price increase in each locality can only immediately attract products from the nearest localities, and not from the remote localities due to transportation costs. As a result, in the short-term, price can only be constant within a given area. Furthermore, the classic Ricardian model ignores the interactions that may exist between different localities. For example, Rogers (1995) and Polsky (2004) explain the influence that some farmers in one area can have on others when they are in contact. These criticisms have recently led some authors to consider the spatial approach in the analysis of the relationship between agriculture (Schlenker et al., 2006; Dall'erba and Domínguez, 2016; Vaitkeviciute et al., 2019) and climate in addition to the other methods still in use in the literature.

Studies carried out in Côte d'Ivoire focused on the analysis of variance (ANOVA) which relates climatic parameters and a specific crop production through the correlation coefficient (Dibi Kangah and Mian, 2016; N'da, 2016). However, this approach is limited insofar as it does not enable capture of the marginal effects of climate parameters on agricultural production. In addition, it omits both the spillover effects induced by some variables on the variable of interest and the possible non-linear effects of climatic parameters on agricultural production.

Our study is more in line with the dynamics of the spatial Ricardian model and aims to analyse the effect of climate change on agricultural income in Côte d'Ivoire. We adopted the empirical model specification, Spatial Durbin Error Model, which captures both the direct and indirect marginal effects of climate as well as those of other explanatory variables responsible for spatial dependence. In addition, this specification accounts for the spatial autocorrelation induced by omitted variables. The analyses are made using survey data from the World Bank database (CGAP 2016) on small agricultural households in Côte d'Ivoire and satellite data from the Climate Research Unit. (Harris et al., 2020). In general, the results show that rainfall has a total non-linear effect (in the shape of an inverted U) on the net agricultural income in Côte d'Ivoire as shown by previous studies (Kurukulasuriya and Mendelsohn, 2008a; Ouédraogo, 2012). However, this total effect is broken down into two effects: a direct non-linear effect and a positive and linear spillover effect within a radius of 50 kilometres. In addition, the analysis of the marginal effects shows that all the regions of Côte d'Ivoire are not affected by rainfall in the same way. Furthermore, some variables such as cooperatives and average household size also have spillover effects on net agricultural income in Côte d'Ivoire. These latter results are not reflected in the previous literature. This absence is probably because previous studies did not consider the spatial autocorrelation induced by these variables.

In view of the above, this study advances the existing literature in several directions. First, it provides theoretical proof of the questioning of the hypothesis of spatial constancy of prices in the classical Ricardian model, and then adopts a spatial approach instead. In addition, it establishes a clear distinction between the direct and indirect effects of climate variables as well as those of other explanatory variables on net agricultural income in Côte d'Ivoire. Finally, it assesses the marginal effects of climate variables on each of the studied localities and then carries out a forecast analysis in order to assess the future effects of the climate on net agricultural income in Côte d'Ivoire.

Market structure for agricultural products in rural areas of Côte d'Ivoire

Agricultural activity is mainly motivated by self-consumption and income. This last objective naturally depends on agricultural production, but also on the prices of products which are themselves strongly influenced by the structure of agricultural markets. Indeed, the size of the market, the barriers to market access and the flow of information are all factors that define the price formation mechanism and the direction of product flows from one market to another. In developing countries in general, the type of product (cash crop or food crop) also defines how the market works. In Côte d'Ivoire the agricultural market may be subdivided into two main

groups: the market for cash crops and that of food crops. In the cash crop market, the government sets prices for producers (farm gate price). However, the effective exchange of products is most often done through negotiations between producers and agricultural cooperatives, which act as intermediaries between farmers and buyers. These negotiations usually result in prices lower than the farm gate price and are different across localities. The argument in favour of cooperatives is that the difficulty of accessing some of the production areas results in significant transportation or transaction costs that these cooperatives will have to bear.

Food crops are sold in local markets (rural and urban) where prices are set by the law of supply and demand. For these food crops, rural markets are characterized by an extreme asymmetry of relations between many small producers and/or consumers and a few buyers and/or sellers. Such market relations are inequitable, often uncompetitive and generally to the disadvantage of the small-scale producer. They result from several factors. The first is the physical aspect which is characterized by a total lack of roads or impassable roads at crucial times of the year. This results in high transportation and/or transaction costs for both buyers and sellers. The second aspect relates to the scale of the market. In many rural communities, especially those in more remote areas where population density is low, low demand for factors of production and the resulting low production attracts very few buyers. As a result, the markets mostly have effect are held once per week and the prices remain very low and vary significantly from one locality to another, depending on the abundance of produce. These disparities in the prices of agricultural products in rural markets lead to rural producers moving to the nearest towns, according to market day. However, this movement of products is limited by several factors that prevent mobility, the most significant of which is the transportation cost positively correlated with distance and road conditions. Therefore, the decision of households to sell their production on a given market results in a trade-off.

Data sources

We used two types of data: socio-economic and climate. Socio-economic data were derived from the World Bank database survey (CGAP, 2016) on small agricultural households in Côte d'Ivoire. This survey was carried out using three questionnaires. The first questionnaire deals with basic household information (property and characteristics of the home) and is addressed to the head of the household or an informed adult. The second is addressed to all household members over 15 years old, participating in household agricultural activities. This questionnaire deals with demographic data, agricultural activities and economic data of the household. The third questionnaire is addressed to an adult randomly chosen from the household and deals overall with agricultural activities, and

formal or informal financial tools. We therefore reconciled these three databases using the household identifier. This allowed us to obtain a database with all the questions (answers) of the unique respondents for each household, in this case the heads of households. From the question relating to the municipality of residence, these households were then distributed over 510 localities covering the entire country (municipalities) and which constitute the analysis sample. In other words, data were aggregated so that each locality represents the average agricultural household living in this locality.

As for the climate data, it comes from the C.R.U. TS 4.03 data (Climate Research Unit of University of East Anglia). The C.R.U. are the result of data derived from observations, generated through spatialization processes (Harris et al., 2020) for each of the regions surveyed. C.R.U. data are at monthly time step and at a spatial resolution of $0.5^\circ \times 0.5^\circ$.

Conclusion and policy recommendations

Climate disturbances resulting from the gradual warming of the planet affect the agriculture sector and lead to economic, technological, and social changes that differ from one country to another. In Côte d'Ivoire climate variability, observed since the 1960s has led to instability in agricultural production which in turn has created economic and social disruptions in several regions of the country.

Given the strong dependence of populations on agricultural production, this study assessed the effect of climate variability on the incomes of smallholder farmers in Côte d'Ivoire. From a simple theoretical model, the study shows that in presence of market imperfection, the hypothesis of spatial constancy of agricultural products prices does not hold. Indeed, the study shows that several factors, such as distance and road condition, affect the mobility of agricultural products, thus creating spatial heterogeneity in the prices of agricultural products, which in turn results in spatial autocorrelation.

These results therefore lead to the adoption of a spatial approach to empirically analyse the effect of rainfall and temperature on the agricultural income of smallholder farmers. The empirical results show that temperature does not affect agricultural income while rainfall in a given locality induces both a direct non-linear effect on that locality and a positive linear spillover effect on agricultural income of neighbouring regions. In addition, the distribution of the total marginal effect of climate on income indicates that an increase in precipitation leads to an increase in the income of farmers in the north and centre while this same effect would lead to a fall in income in the coast and in the western region.

Furthermore, the impacts of the future climate, based on the Intergovernmental Panel on Climate Change (IPCC) forecasts, indicate that an average decrease or increase in rainfall of between 5% and 10%, leads to a drop in the average income of Ivorian agricultural households. Moreover, the results also show that agricultural cooperatives as well as family labour have direct positive effects on household income, but indirect negative effects on household income in neighbouring localities.

These results, especially those of the total marginal impacts, suggest economic policies linked to the fight against climate change. Indeed, current policies, both adaptation and mitigation, are addressed comprehensively. Of course, they take into account vulnerable sectors, but do not make an objective difference between the populations who could be the most vulnerable, especially in the agriculture sector. Thus, we suggest that, given the strong influence of the climate on household income in the centre and north, policies to support farmers in terms of subsidies for the availability of seedlings and information on climate forecasts be more accentuated in these regions.

In addition, the central, northern, and eastern regions must benefit from support at the level of local communities in order to enable them to submit viable adaptation projects that could affect the daily lives of these agricultural households. For example, strategies geared towards irrigation policies could be beneficial insofar as water supply would play the same role of increased rainfall. For coastal and western farmers, training in drainage techniques or rainwater management could help them increase their income. Finally, a better organization of agricultural cooperatives must be undertaken, especially for small agricultural households.

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