Econometric Approach to Measuring Climate Change Effects on the Agricultural Productivity: Evidence from Morocco*

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Abstract

Climate change (temperature and rainfall) affects agricultural productivity, especially the growing conditions of crops. This negative impact is considered as the main obstacle to the realization of the first Millennium Development Goal of reducing food insecurity and poverty in poorest countries. In this paper, we provide some insights into the relationship between annual variations in temperature and rainfall, and annual agricultural productivity. Our study is based on Diebold and Yilmaz econometric methodology (2012), to measure the degree of connectedness and assess spillover effects transmission between the above variables. The sampling frequency data is annual and covers the period 1980 - 2016. The empirical results indicate varying degrees of interdependence and effects transmission among temperature, rainfall and agricultural productivity. It is highlighted a substantial increase in spillover effect and interaction in critical periods, more precisely the influence of the climate conditions on annual crops. Overall, the results confirm the deep relationships between rainfall and agricultural productivity in Morocco. In fact, rainfall has a positive effect during the last decade, which was accompanied by the threat of temperature rises.

Keywords: Spillover index, Rainfall, Temperature, Variance decomposition.

*The views expressed here are those of the authors and do not necessarily represent or reflect the views of their institutions.

1 Introduction

Climatic impacts determine the performance of agriculture in assuring economic growth with food for population. Thus, agricultural policies should tend to reduce its negative effects by adopting efficient strategies. In Morocco, rainfall and temperature, are likely to have an impact on agricultural production, which is a threat to the livelihood of smallholder farmers, because agricultural sector represents more than 40% of labor force as the first employer sector, and it contributes with 14% of Moroccan Gross Domestic Product. This problematic make researchers, and specialists more interested in developing analytical tools, to facilitate decision making. Very few studies have interested to the relationship between climate variability and agricultural productivity in Morocco. Generally the previous studies show that the change of rainfall and temperature reduce yields cereals and food crops.

The link between climate change and agricultural productivity has attracted the attention of many researchers in applied econometrics on environmental and agricultural economics. There are specific types of econometric models that can be applied;

- Weighted Ordinary Least Squares model (Mendelsohn, Nordhaus, and Shaw (1994));
- Spatially correlated error model (Schlenker, Hanemann, and Fisher (2006));
- A panel model with fixed effects (Deschenes and Greenstone (2007)).

Fischer and Velthuizen (1996), based on empirical investigations of weather and climate impacts in Kenya, show that rainfall and precipitation are likely to have positive effects on agriculture in highland areas. However, the most studies of climate change expect losses. Indeed, Reilly et al. (1994) estimate that the global welfare changes in the agriculture sector are approximated between losses of 61.2 billion and gains of 0.1 billion. Many of these study results argue that an important evolution in temperature or rainfall tend to a decline in production. For instance, Aggarawal and Sinha (1993) demonstrate that a rise by 2°C in temperature decrease rice yield in India at the rate of 0.71 ton per hectare, while a 1°C increase in temperature have no significant effect on yields.

The aim of our paper is to investigate empirically the spillover effects of climate variability on the agricultural productivity in Morocco. We adopt the Diebold and Yilmaz approach, which measures the relative importance of spillovers at different points in time; A higher spillover index indicates a stronger connectedness between climate changes and agricultural productivity. The paper is organized as follows. The second section describes the Diebold and Yilmaz methodology, then, we outline in section 3 our data and some descriptive statistics. Section 4 provides the full sample estimation results and their discussions. Section 5 concludes.

2 Diebold and Yilmaz Methodology

The construction of the Diebold and Yilmaz (2012) spillover index relies on forecast error variance decompositions. They show the proportion of the movement in a variable's development due to its own shocks and other variables shocks by quantifying how much of the total variance forecast is attributed to each variable. They use the generalized VAR framework of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998). We Consider N-variable vector modeled as a p^{th}-order stationary VAR:

$$y_t = \sum_{i=1}^{P} \Pi_i y_{t-i} + \varepsilon_t, \qquad \varepsilon_t \rightsquigarrow i.i.d(0, \Sigma). \tag{1}$$

The moving average representation:

$$y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i}. \tag{2}$$

The Koop et al. (1996), Pesaran and Shin (1998) (the KPPS hereafter) H-step-ahead forecast error variance decomposition is:

$$d_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' A_h \Sigma A_h' e_i)}, \quad where: \tag{3}$$

σ_{jj} is the standard deviation of the error term for the j^{th} equation;

e_i is the selection vector with 1 as the i^{th} element and 0 otherwise;

Σ is the variance matrix for the error vector ε. Each entry of the variance decomposition matrix is normalized:

$$\tilde{d}_{ij}^{g}(H) = \frac{d_{ij}^{g}}{\sum_{j=1}^{N} d_{ij}^{g}}. \tag{4}$$

Total spillover index determines the contribution of innovations (or effects) across all variables to the total forecast error variance:

$$S^g(H) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{d}_{ij}^{g}(H)}{\sum_{i,j=1}^{N} \tilde{d}_{ij}^{g}(H)} \times 100 = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{d}_{ij}^{g}(H)}{N} \times 100. \tag{5}$$

3 Data and descriptive Statistics

Morocco has three main environmental zones: The coastal region to the north with dry summers and mild wet winters, also, the Rif and Atlas mountains characterized by cold temperature, and massive rainfall, with snowing winter. Then, the Desert in southern part of Morocco enjoying with hot summer and no precipitation. Our yearly data covers the period 1980-2016, describing the Moroccan climate and agricultural situation during the last 37 years (Cf Figure 1).

- Moroccan agricultural productivity (q/ha); raised by four during this last thirty years, however, there were some moments of severe decreases e.g. (1995, 2007, 2012).

- Annual average temperature (°C): it increased by approximately 2°C during this last decade in Morocco.

- Total Annual Rainfall(mm), it is indicated that during last decades, rainfall appears irregular and instable.

We compute variation rate for each variable series V_{it}:

$$Variation.rate = 100 * \frac{V_{it} - V_{i(t-1)}}{V_{i(t-1)}}. \tag{6}$$

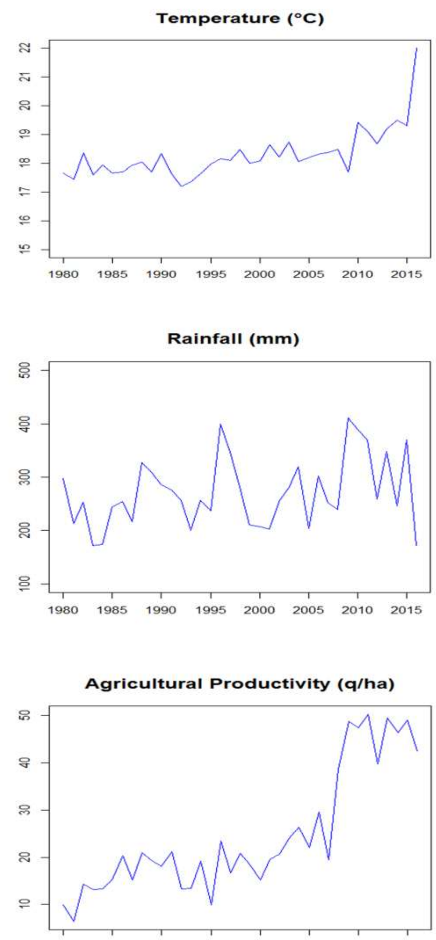

Fig. 1. Climate and Agricultural productivity annual data

We perform unit root tests by using the classic Augmented Dickey-Fuller (ADF) approach to determine the stationary properties of the above variation rate series. The results reveal that all series are stationary and integrated of the order 0.

4 Empirical Analysis

In this section, we assess spillover effects across different tables of measure. In this framework, we study both static full-sample analysis and dynamic rolling-sample analysis to make our study more interesting and expressive. Then, we discuss some environmental and agricultural insights of Morocco, focused on the impact of climatic change on agricultural productivity during the last decades.

4.1 Total Spillover index

In this subsection, we present the description of the static spillover index, for variation rate of climate variable and agricultural productivity. Table 1 indicates that gross directional spillovers "to others" and "from others to" are important for agricultural productivity and rainfall. As for net directional spillovers, their values are presented in the following Table:

Tab. 1. Net directional spillovers between climate conditions and agricultural productivity

Variables	To others	From others	Net directional spillovers
TEMPERATURE	2.1	2.6	**-0.5**
RAINFALL	22.2	21.8	**0.4**
AGRICULTURAL PRODUCTIVITY	21.7	21.6	**0.1**

This result shows that rainfall is the main responsible of transmitting spillover effects to agriculture and temperature.

Hence, its positive net directional spillovers proves that it has influence on others factors. In fact rainfall in Morocco doesn't only determine environmental and agricultural conditions, but it affects the economic growth as well through the agricultural sector.

We see in Table 2, that agricultural productivity is clearly in a situation of receiving spillovers, transmitted from rainfall(20.7% of spillover effects), while temperature variable hasn't really shock effect on agriculture.

Tab. 2. Spillover effects from climate conditions to agricultural productivity

	TEMPERATURE	RAINFALL	AGRICULTURAL PRODUCTIVITY
to AGRICULTURAL PRODUCTIVITY	0.9	20.7	78.4

Table 3 shows relative effects transmission, indeed, almost 15.33% of forecast error variance comes from spillovers and shocks.

Tab. 3. Spillover index between climate conditions and agricultural productivity

	From others
TEMPERATURE	2.6
RAINFALL	21.8
AGRICULTURAL PRODUCTIVITY	21.6
TOTAL	**46**
SPLILLOVER INDEX	$\frac{46}{300} = \mathbf{15.3\%}$

4.2 Dynamic Spillover index

We describe here the dynamic spillover indexes based on 16-year rolling samples and 1 year ahead variation forecast errors (Figure 2). Before 2005, spillover index was relatively eventful (between 25% and 44%, particularly the crop year 2006-2007 which was characterized by a serious rainfall deficit accentuated by very poor agricultural production). After that, the spillover index plot displays a decrease movement due to stability in agricultural production, particularly from 2010 to 2015 (less than 27%).

These Strong bursts and high Spillover variations observed in the spillover plot, characterize effectively a sudden drop or rise in variation rates, where some of them are presented below:

- **2006 - 2007:** This season was characterized by a really decreasing in rainfall aggravated by the strong cold spell and intense drought in the Moroccan countryside. Due to these Climatic shocks, agricultural productivity was seriousely affected.

- **2010 - 2015:** After the launch of "Plan Maroc Vert" in 2008 in order to limit damage caused by climate conditions. The agriculture has succeded in achieving its top gains of productivity despite some extreme precipitation events and increased temperatures. This situation contributes to the decline in the spillover indices.

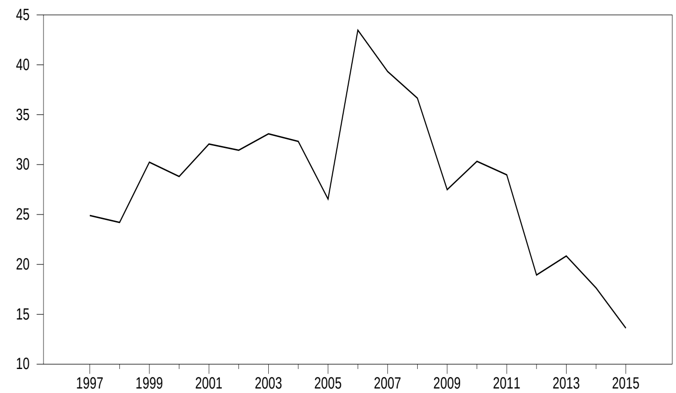

Fig. 2. Dynamic Spillover index plot

4.3 Discussions and analyses

The characterization of the climatic conditions during the last decades in Morocco showed an increase in the droughts and inundations frequency. This dynamic is associated to the global climatic change that makes agriculture, more and more submissive to the climate shocks mainly rainfall. Consequently, Morocco lives during the last decade the longest dry episode, characterized by lack of the precipitation and a tendency to the increase in temperature.

In the past, Morocco used agricultural incentives to counter drought effects. Actually, to increase resilience against climatic change, agricultural policies should move from maximizing agricultural profit to stabilizing it (Schilling et al. (2012)).

Furthermore, Morocco is facing a risk of water lack for food security, it is increasing due to droughts and domestic needs. Therefore, it will be important to conduct strategies to reduce losses and improving water use efficiency. For this reason, evaluating an adaptive capacity index is necessary. In this framework, Iglesias et al. (2011) propose an adaptive capacity index as an agricultural innovation to assist stakeholders develop measures to reduce the vulnerability. Finally, the agriculture sector in Morocco will remain vulnerable to climate variability, unless early warning systems are implemented for decision makers (Balaghi et al. (2007)).

5 Conclusion

Climate change affects agricultural production, especially the growing conditions of crops, which is considered as a threat of food insecurity in developing and poorest countries. In this paper, based on Diebold and Yilmaz econometric methodology, we provided some insights into the relationship between annual variations in temperature and rainfall, and annual agricultural productivity. The sampling frequency data is annual and covers the period 1980-2016. The empirical results indicate varying degrees of connectedness and spillover effects transmission from climatic change to the agricultural production.

In light of these findings, the results confirm the deep relationships between rainfall and agriculture in Morocco. In fact, the agricultural productivity has been most affected by rainfall variability, but not influenced by temperature increases during the last decade. Thus, insurance measures should be implemented to protect farmers from exposure to increasingly climate-related risks such as extreme rainfall events and temperature rises.

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