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AN APPLICATION OF VECTOR ERROR CORRECTION MODEL TO ANALYZE THE IMPACT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY IN INDIA'S NORTH-EASTERN REGION

Utpal Kumar DE*

Department of Economics, North-Eastern Hill University, Shillong, India

and

Girijasankar MALLIK**

School of Business (Parramatta Campus), Western Sydney University, NSW, Australia

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Abstract: Unlike crop specific productivity analysis, this study tries to analyse the impact of climate change and relevant variables on the overall agricultural productivity using panel data. Using Panel cointegration this study found a long run relationship among CPI, Khariff/Rabi maximum temperature, Fertilizer, GCA and annual rainfall. The cointegration relationship shows an inverse relationship of both Khariff and Rabi maximum temperature on the overall agricultural productivity, while rainfall has positive and significant impact. The expansion of area under cultivation is observed to have negative impact indicating the limitation of maintaining the productivity for extension to lesser productive areas. However, the vector error correction shows a remote lag inverse relation of rainfall on the current agricultural productivity.

Key words: Panel co-integration, VECM, composite agricultural productivity, assam.

JEL Classification Number: C33, Q19, Q54, Q51, R52, R11.

1. INTRODUCTION

Productivity of agriculture has been under continuous threat throughout the decades with the changing agro-climatic conditions despite the fact that general productivity level in agriculture has increased due to increasing application of modern agro-technology (Karim, Hussain and Ahmed 1996; Mahmood, Legates and Meo 2004; Rashid and Islam 2007; Lobell, Cahill and Field 2007; Lobell and Field 2007; Deschenes and Greenstone 2007; Guiteras 2007; Kim and Pang 2009; Feng, Krueger and

E-mail: *utpalkde@gmail.com; de_u@yahoo.com **G. Mallik@westernsydney.edu.au

Oppenheimer 2010; Joshi, Maharjan and Luni 2011). Studies have revealed ambiguous results in regard to the growth of agricultural productivity across the regions of the world (Chen, McCarl and Schimmelpfennig 2004; Sarker, Alam and Gow 2012; Iqbal and Siddique 2013). As climatic factors change variedly across regions, their effects also differ regionally due to variation in geo-morphological, agro-climatic conditions and cropping pattern. Moreover, different crops have different sensitivity and that also varies widely across zones and seasons, the climate change effects also reflect differential results (Ruttan 2002; Almaraz et al. 2008). In several places global warming, fluctuating precipitation caused decline in yields and productions of some crops (Isik and Devadoss 2006; Almaraz et al. 2008; Basak, Ali, Islam and Rashid 2010), while in some regions it caused short term increase in output potential (Olesen and Bindi 2002; Ruttan 2002; Chen, McCarl and Schimmelpfennig, 2004; Reilly et al. 2007; Benhin 2007).

Global warming has direct and indirect impacts on the agricultural productivity. Rising temperature enhances productivity for some crops while that is often counterbalanced by sustained rise in CO_2 before level or fluctuating precipitation (Benhin 2007; Kim and Pang 2009). The opposite case is also observed for grain yields (Karim, Hussain and Ahmed 1996; Islam, Huq and Ali 1999 Reilly 2007). Indirectly, climate change has significant impacts on water resources, food security, hydropower, human health and also aggravate incidence of pest especially for African countries, as well as to the whole world (Isik and Devadoss 2006; Rashid and Islam 2007). Experiences across regions of India reveal that because of changing rainfall patterns and depletion of water resources, the existing cropping pattern is becoming less productive (Sivanandan 1983; Venkateswarlu 2009; Pachauri 2009; Guiteras 2007). Thus various adaptation measures and changing cropping practices are followed to counter the climate change impacts on productivity and disperse risk (Olesen and Bindi 2002; Dmitri et al. 2005; Hoppe et al. 2009; O'Donoghue et al. 2011; Walthall 2012; De and Bodosa 2015). Intensification of crops through mixed cropping and integration of high-value crops such as horticultural production is gaining prominence as a climate change adaptation strategy, especially in the hill regions. Application of improved technology like chemical fertiliser, irrigation with appropriate choice of cropping pattern has in many cases offset the effect of growing uncertain and adverse climate.

This paper tries to examine the long run relationship between the climate change along with technological inputs on the overall agricultural productivity in Assam the largest agricultural state of North-East India where more the seventy per cent of the population are dependent on agriculture and its associated sector for their survival.

2. THE THEORETICAL BACKGROUND

Impact of climate change on the agricultural productivity has been examined by the researchers in a number of ways. Crop productivity is one of the primary considerations to directly link with the temporal variation in weather components across the zones. Application of crop productivity models to climatic impact assessment includes procedures based on statistical (regression) and/or simulation techniques, and to a large extent, follow the development of crop productivity models in general (Baier, 1979; Biswas, 1980). In this approach, yields of individual crops are regressed on multiple predictor variables. By using historical climatic and yield data for specific crops in particular areas, regression equations have been used to predict the changes in yields expected due to alterations in climate (Lough et al. 1983; Santer 1984; Deschenes and Greenstone 2007; Guiteras 2007; Iqbal and Siddique 2013). Most of these studies suffer from the limitation of reflecting true independence among the predictor variables, especially those related to agro-climatic properties, such as length of growing season and soil moisture, and the extension of the statistical relationships beyond the range of conditions for which they were developed (Parry and Carter 1988). In the simulation based models, a set of mathematical equations are combined based on experiments or knowledge of specific plant processes (photosynthesis, respiration, and transpiration) and their interactions with the environment (climate and soils) to forecast the potential changes in yields. Though there is always a doubt about the ability of simulation models to capture and integrate specific plant processes and predict future due to uncertain external shock and future climate, this approach to productivity modelling sometimes better suited to estimating yield changes due to climatic modifications than empirical statistical regression models (Parry and Carter 1989).

As mentioned earlier, individual crop yield in most of the cases are linked with weather variables of that growing season along with the technological variables to examine the impacts of individual factors. In many cases the adverse climate change impact is counterbalanced by the technological factors (developed more temperature and water resilient seeds to adjust with rising temperature, available varieties of shorter duration to adjust with the reduced rainfall, avoid uncertain extreme climatic events like flash flood, storm etc). Also, effect of changing one variable like temperature or CO_2 emission is counterbalanced by changing seasonal rainfall, sunshine. All the weather variables are found to have a close relationship and also there is a significant correlation among the use of irrigation, chemical fertiliser and HYV seeds. Hence, one has to choose the correct variables in estimating the relationship between the climate variables and the yield of crops. There is always a significantly high correlation among the weather related variables like temperature, precipitation, humidity and sunshine (De, Pal and Bodosa 2015; De and Bodosa 2014). There is a significant correlation between the use of chemical fertiliser and irrigation. Also, spurious relation among various variables over time cannot be ignored under such cases.

It is often found that the farmers adopt some climate change adaptation mechanism to maintain their agricultural earning and disperse climate related risk. Changing diversity of crop for a suitable adjustment with the changing climate and to moderate the effect of possible extreme climate impact is prominently observed as a climate change adaptation strategy. The trend of cropping choice depends on the micro level experience of famers and their capacity to adjust by ushering suitable technology with their technical knowhow, financial position and institutional support. The same varies across the zone due to spatial zonal variation in geographical conditions. Hence, it is important to examine the impact of spatio-temporal change in climatic indicators and technology on overall agricultural productivity. In the process differential impacts on crop yields of rising temperature, precipitation etc is captured along with the changes in proportional allocation of land towards different crops.

In the regression analysis in most of the cases, researchers used simple or generalised least square techniques. For a multiregional data analysis they used fixed effect panel data regression analysis by incorporating zonal and time dummies. Our analytical procedure is bit different from that of previous researchers. In this analysis, a panel cointegration analysis is followed for analysing the district level temporal variation in composite agricultural productivity as a function of major climate related variables maximum temperature in Rabi and Khariff Seasons, annual total rainfall across the zones (here districts), use of chemical fertiliser and gross cropped areas representing the scale of activity. The effect of spatial or regional characteristics specifically for the hills and plains/valleys can be obtained by introducing a dummy variable.

According to theory vector error correction model the temporal adjustment has applied if the variables found to be conintegrated and that can be captured by using the changes in lagged composite productivity along with the changes in other explanatory variables for analysing the current period variation in the composite productivity where changes in proportional allocation of land towards various crops are included along with the relative yields of crops.

3. DATA AND EMPIRICAL MODEL

Annual data has been computed from monthly data on maximum and minimum temperature, morning and evening humidity and rainfall etc of last six decades, collected from the India Meteorological Department (IMD) for all ten zones of Assam. These ten zones where meteorological stations are there correspond to the original ten districts of Assam existing in 1950. From there annual data on average rainfall, maximum and minimum temperature, humidity etc have been computed for the period 1951 to 2010. Also, area, production and yield, of all the crops, consumption of chemical fertiliser, irrigation capacity from different sources, incidence of flood across the districts of Assam have been collected from various issues of *Statistical Hand Book* of Assam, *Economic Survey of Assam* and Reports from Directorate of Economics and Statistics and Directorate of Agriculture, Government of Assam.

Productivities of different crops are non-comparable in quantitative terms for their heterogeneity. It is possible only if they are converted into value terms. But data on prices of crops for all the years are not available. Here the term agricultural productivity is used to denote a composite unit, which is based upon the yields of different crops as well as allocation of land for the cultivation of various crops. The index is constituted to describe the overall productivity of the districts vis-a-vis the state average. First, a *yield relative* has been calculated for different crops in different districts as $R_{ij} = (Y_{ij}/Y_{i0}) * 100$, where Y_{ij} is the average yield of i^{th} crop in the j^{th} district and Y_{io} represents the average yield of i^{th} crop in the state. R_{ij} is the yield relative for i^{th} crop in j^{th} district. In order to have inter-district comparison, composite productivity index is constituted for each district separately by taking into account the variety of crops and their relative importance given by the farmers of the districts in terms of the proportional allocation of area to each crop to total cropped area in each district and then added up to get the *composite productivity index* (CPI). C*omposite Productivity Index* (CPI) for the j^{th} district can be written as $CPI_j = \sum_i (Y_{ij}/Y_{i0}).\ (A_{ij}/A_{i0}) * 100$ where $A_{i0} = \sum A_{ij}$ and A_{ij}/A_{i0} = proportion of area under i^{th} crop to total cropped area in j^{th} district ($j = 1, 2, \ldots, 10$). Here the productivity captures both the yields of crops of the zone relative to the state average and cropping pattern in terms of proportion of area under different crops.

Though several studies used earnings from the production of crops in order to compute the diversity index, here we use area under crops for the purpose. This is because the farmers try to maximise the returns from their limited land keeping in view the sustainable income possibilities. The land size allocation to different crops reflects the intention of the farmers which may not be realized in the same way through production. Moreover, the area of crop cultivation is more robust than the output, which is subject to available technology at the time of production and to the weather pattern of that season.

Individual crop yields may experience different types of shocks for the changes in same weather variable like temperature or rainfall, the net or overall impact of the same weather variable on agricultural productivity of a region would be reflected when composite productivity is analysed in respect of such weather variable. Moreover, through changing proportional land allocation to crop cultivation (already taken into account in the composite productivity) one major adaptation mechanism of the farmers as a response towards climatic uncertainty over time is explained.

Data constitutes of variables for different districts of the same state Assam for the same time period constitutes a balanced panel. Therefore it is possible to perform a time series analysis for all the districts as a whole. It is to be noted that we have performed the co-integration analysis (not shown here) for individual 10 districts and found that these same variables are co-integrated. We found that panel data analysis will be most appropriate at least in this situation. We use the following models to describe the following long run relationships among the variables under study.

$$\ln \mathrm{CPI}_{it} = \alpha_1 + \beta_{11} \ln \mathrm{RAB}_{it} + \beta_{12} \ln \mathrm{FERT}_{it} + \beta_{13} \ln \mathrm{GCA}_{it} + \beta_{14} \ln \mathrm{RAIN}_{it} + \varepsilon_{1it} \qquad (1)$$

$$\ln \mathrm{CPI}_{it} = \alpha_2 + \beta_{21} \ln KH_{it} + \beta_{22} \ln \mathrm{FERT}_{it} + \beta_{23} \ln \mathrm{GCA}_{it} + \beta_{24} \ln \mathrm{RAI}N_{it} + \varepsilon_{2it} \qquad (2)$$

Here CPI represents composite productivity index, RAB, KH, RAIN, GCA, and FERT represent maximum temperature in rabi season, maximum temperature in khariff season, total annual rainfall, Gross Cropped Area and fertiliser intensity respectively. The suffix i, refers to the district and t refers to the time period 1951–2010 and ε_{1it} and ε_{2it} are random error term, assumed to be normally distributed with zero mean and a finite heterogeneous variance. Dhill is the dummy variable entered in the equations that takes value 1 for hill districts while it takes value zero if not a hill zone.

As there is significantly positive correlation in the regional changes in maximum and minimum temperature over time, here maximum temperature is considered. Maximum temperature in Khariff (summer) season has effect on major Khariff crop like paddy which is different from effect that maximum temperature in Rabi (winter) season has on the winter crops like wheat, potato, mustard etc. Since the composite incorporates the yield relatives of all the crops, here both the maximum temperature in Khariff and Rabi seasons are included but separately in tow different equations. In both cases the overall rainfall is considered since quantum of rainfall in monsoon also affect the productivity in other seasons through the changing capacity of irrigation. It is however a fact that the sudden flash flood for heavy precipitation in a few days of harvesting season can adversely affect the yield of current on field crops, while the continuous moderate rainfall positively affect the productivity across the seasons. In order to avoid severe multicollinearity, irrigation (an important variable for controlling productivity through yield and area allocation during off-monsoon seasons) is also not included in the analysis. Overall area has a scale impact on the productivity by allowing farmers to use various technologies like machineries and management practices and thus included here as another variable.

The first task is to estimate the parameters in equation (1) and (2) using panel cointegartion and conduct some panel tests using appropriate method of the variables in their first difference to find out the causal relationships of the growth effects of the variables (Pedroni 2004). It is expected that coefficient of lnRAIN will be positive and significant implying that an increase in overall rainfall may increase the CPI as water is very important for major rice cultivation and through increasing the capacity of irrigation in other seasons. However, heavy and sudden rainfall during harvesting or scanty and delayed rainfall in showing season can also affect yield of current field crops. Similarly, chemical fertiliser is expected to have positive effect on the productivity. Maximum temperature in the summer having adequate irrigation has positive impacts on summer crops like paddy while in winter may have negative impact of yield potato, mustard etc. So the impact on overall productivity would be a mix. The impact of GCA due to its negative impact on management and general feature of expansion of cultivation over the relatively less productive land after the exhaustion of most productive lands is expected to have negative impact on productivity.

Hill areas in Assam is found to exhibit diversification towards inferior crops due to scarcity of irrigation and other adverse conditions of the farmers including the scarcity of capital (as shown by De and Bodosa 2015) is expected to exhibit negative impact on overall yield over time. The farmers however, try their best to get maximum benefit from their limited plots. It is however, excluded from the co-integration and shown in the long run relationship of vector error correction model.

Thus this study intends to test i) the long run relationship among the variables using panel cointegration for two sets of variables as per equation (1) and (2); ii) if cointegration exists, estimate the coefficients of the long run relationship and iii) estimate the short run relationship using Vector Error Correction Method (VECM) in a multivariate dynamic framework.

4. ECONOMETRIC ANALYSIS AND EMPIRICAL RESULTS

As mentioned above, the objective of this study is to test whether there exist long run relationship among the variables composite agricultural productivity, climatic variables like temperature (here maximum temperature only), rainfall, application of chemical fertiliser, overall cultivated are (GCA) and geographical condition (hill, valley or plain). The testing procedure consists of two steps: panel cointegration test and VECM.

In panel data analysis, particularly for cointegration, an essential first step is to identify the stationary properties of the variables (Im, Pesaran and Shin 2003;). While there are number of panel unit root tests, (Pedroni 2004; in this study we use three panel unit root tests (Levin- Lin- Chu: LLC, and Fisher-types: ADF and PP tests) proposed by Levin et al. (2002), Maddala and Wu (1999) and Choi (2001) respectively. These tests are widely used in most of the papers and hence, we do not repeat the detail methodologies here. The null hypothesis of the above three unit root tests is that there exist unit root in the series, i.e. the variables are non-stationary.

Pedroni (1999) advocates two statistics both based on a group-mean approach. The Group PP is non-parametric and analogous to the Phillips-Perron t statistic and Group ADF is a parametric statistics and analogous to the ADF t statistic. These two statistics are referred to as between-dimension statistics that average the estimated autoregressive coefficients for each country.

Under the alternative hypothesis of cointegration, the autoregressive coefficient is allowed to vary across districts. This allows one to model an additional source of potential heterogeneity across districts[1]. Following an appropriate standardisation, both of these statistics tend to standard normal distribution as N, T $\rightarrow \infty$ diverging to negative infinity under the alternative hypothesis and consequently, the left tail of the normal distribution is used to reject the null hypothesis of non-cointegration.

The results of panel cointegration test, based on Group PP and Group ADF statistics, are shown in Table 3. It can be seen that these two statistics are significant at 1% level. So, the null hypothesis of no cointegration can be rejected.

On the basis of unit root and cointegration test results in the above, the following vector error correction models (VECMs) are used to know the short- run fluctuations and long- run equilibrium (Westerlund 2007).

$$\Delta \ln \mathrm{CPI}_{it} = \alpha_{10} + \sum_{k=1}^{p} \beta_{1k} \Delta \ln \mathrm{CPI}_{it-k} + \sum_{k=1}^{p} \lambda_{1k} \Delta \ln \mathrm{RAB}_{it-k}$$

[1] Pedroni (1999) also proposes four within-dimension statistics [panel v-statistic, panel ρ-statistic, panel t-statistic (non-parametric) and panel t-statistic (parametric)] that affectively pool the autoregressive coefficients across different countries during the unit root tests. In these tests, a common value for the autoregressive coefficient is specified under the alternative hypothesis of cointegration.

Table 1: Summary Statistics and description of the variables

Variable	Description of the variables	Mean	Maximum	Minimum	Std. Dev.
ln CPI	Composite Productivity Index	4.622	5.089	4.182	0.144
ln RAB	Maximum Rabi temperature	3.251	3.411	3.059	0.063
ln KH	Maximum Khariff temperature	3.4	3.508	3.245	0.056
ln FERT	Fertilizer Intensity	1.352	4.893	−2.578	1.452
ln GCA	Gross Cropped Area	12.314	13.499	9.143	1.014
ln RAIN	Annual Rainfall	7.741	8.416	6.918	0.289

Note: where, "ln" represents the natural logarithm

Table 2: Two-way Correlation Matrix among the Variables of Analysis

Panel A: For level variables						
	ln CPI	ln MaxTRAB	ln KH	ln FERT	ln GCA	ln RAIN
ln CPI	1.00					
ln RAB	−0.184	1.00				
ln KH	−0.215	**0.893**	1.00			
ln FERT	−0.205	0.202	0.251	1.00		
ln GCA	0.614	0.219	−0.327	0.433	1.00	
ln RAIN	0.379	0.197	0.034	−0.282	−0.537	1.00

$$+\sum_{k=1}^{p}\pi_{1k}\Delta\ln \mathrm{FERT}_{it-k}+\sum_{k=1}^{p}\delta_{1k}\Delta\ln \mathrm{GCA}_{it-k}$$
$$+\sum_{k=1}^{p}\gamma_{1k}\Delta\ln \mathrm{RAIN}_{it-k}+\eta_1 Dhill_{it}+\kappa_1 \mathrm{ECT}_{1it-1}+\varepsilon_{1it} \quad (3)$$

$$\Delta\ln \mathrm{CPI}_{it}=\alpha_{11}+\sum_{k=1}^{q}\beta_{2k}\Delta\ln \mathrm{CPI}_{it-k}+\sum_{k=1}^{q}\lambda_{2k}\Delta\ln \mathrm{KH}_{it-k}$$
$$+\sum_{k=1}^{q}\pi_{2k}\Delta\ln \mathrm{FERT}_{it-k}+\sum_{k=1}^{q}\delta_{2k}\Delta\ln \mathrm{GCA}_{it-k}$$
$$+\sum_{k=1}^{q}\mu_{2k}\Delta\ln \mathrm{RAIN}_{it-k}+\eta_2 Dhill_{it}+\kappa_2 ECT_{2it-1}+\varepsilon_{2it} \quad (4)$$

Where, ε_{1it} and ε_{2it} are the random error terms and p, q are the lag lengths determined by AIC/SBC criteria. The ECT[2]s is error correction terms. We obtain the ECT that is the residuals from the estimations based in the panel data analysis which is our preferred long-run estimator. The ECTs represent the long run dynamics, while differenced variables represent the short run dynamics between the variables. The Table 4 reports the estimated result of VECM.

[2] Where, $\mathrm{ECT}_{1it-1} = \ln \mathrm{CPI}_{it-1} - \widehat{\alpha_1} - \widehat{\beta_{11}}\ln \mathrm{RAB}_{it-1} - \widehat{\beta_{12}}\ln \mathrm{FERT}_{it-1} - \widehat{\beta_{13}}\ln \mathrm{GCA}_{it-1} - \widehat{\beta_{14}}\ln \mathrm{RAIN}_{it-1}$ and $\mathrm{ECT}_{2it-1} = \ln \mathrm{CPI}_{it-1} - \widehat{\alpha_2} - \widehat{\beta_{21}}\ln \mathrm{KH}_{it-1} - \widehat{\beta_{22}}\ln \mathrm{FERT}_{it-1} - \widehat{\beta_{23}}\ln \mathrm{GCA}_{it-1} - \widehat{\beta_{24}}\ln \mathrm{RAIN}_{it-1}$

Table 3: Results for Panel Cointegration Analysis: (Pedroni Residual Cointegration Test)

Panel A:				
Variables	ln CPI, ln RAB, ln FERT, ln GCA, ln RAIN		ln CPI, ln KH, ln FERT, ln GCA, ln RAIN	
Lag length	2	3	2	3
Panel v-Statistics	−0.1034	−0.1034	0.8522	0.8522
Panel rho-Statistics	−7.2087***	−7.2087***	−5.9098***	−5.9098***
Panel PP-Statistics	−8.6679***	−8.6679***	−8.0839***	−8.0839***
Panel ADF-Statistics	−0.4461**	0.6366	−1.0857**	−0.1810
Panel B:				
Group rho-Statistics	−7.9427***	−7.9427***	−7.3031***	−7.3030***
Group PP-Statistics	−11.3632***	−11.3632***	−10.9380***	−10.9380***
Group ADF-Statistics	−2.4064***	−1.3064*	−2.7302***	−1.6492**
Long run relationships	ln CPI = 7.6546 −1.8701*** ln RAB +0.0301 ln FERT −0.0238 ln GCA +0.4265*** ln RAIN (−3.848) (1.530) (−0.573) (3.318)			
	ln CPI =9.9835–2.4303*** ln KH +0.0186 ln FERT −0.0332 ln GCA +0.4249*** ln RAIN (−4.146) (0.888) (−0.754) (3.340)			
Note: ***, ** and *stands significance at the 1%, 5% and 10% level. T-statistics are in brackets				

Most of the correlation coefficients are statistically insignificant, while correlation between lnRAB and lnKH is very high at 0.893. Therefore it is not possible to consider these two variables in one model.

Since at least 5 out of the 7 statistics in the panel cointegration are significant the variables under study are cointegrated and therefore there should be a long run relationship among the variables and they do not drift apart in the long run. That means the relationship is meaningful. The long run relationship also reveals that rising maximum Rabi as well as Khariff temperatures across the zones adversely affect the composite crop productivity in agriculture. Coefficient of GCA is negative, indicating the reduction in productivity with the expansion of cultivation in various seasons which is in line with the Ricardian argument of use of less productive land with lesser facilities after the exhaustion of the most productive land. Chemical fertiliser as expected has significant positive impact on the productivity in the long run.

In the long run impact of rain on CPI is positively significant (last row of table 3). As both side variables are in natural logarithms, we can consider the coefficients as elasticity implies that one unit increase in rainfall would increase CPI by 0.42 units.

Table 4 shows the short run relationship of CPI with weather variables like maximum temperature, rainfall, chemical fertiliser, GCA and hill dummy. Here, ECM terms are negative and significant at least at 1% level that justifies the long run relationship. The magnitude of the ECM term in column-2 is 0.072 implies that the whole system going to equilibrium and the speed of adjustment is 7.2 percent per annum. DW statistic shows that the serial correlation is absent. The third column also represents the magnitude of ECM term as negative and 0.064, which is an indication of gradual adjustment by 6.4 percent annually and approaching towards equilibrium. Since the composite productivity includes both the relative yields of crops and area allocation as decided by the farmers, the significant negative coefficients are indications of reaching towards optimum value taking technological and weather changes into consideration.

The vector error correction results reflect that impact of lagged changes in temperature is found to be very weak as expected. Gradual changes in temperature in previous

Table 4: Panel Error Correction Model (dependent variable: $\Delta \ln CPI_{it}$)

Variables	(2)	(3)
$ECM_{i(t-1)}$	−0.072*** (−3.39)	0.064*** (−3.242)
$\Delta \ln CPI_{i(t-1)}$	−0.484*** (−10.94)	−0.495*** (−11.25)
$\Delta \ln CPI_{i(t-2)}$	−2.267*** (−5.74)	−0.276*** (−5.93)
$\Delta \ln CPI_{i(t-3)}$	−0.15*** (−3.700)	−0.157*** (−3.743)
$\Delta \ln RAB_{i(t-1)}$	−0.066 (−0.63)	
$\Delta \ln RAB_{i(t-2)}$	0.027 (0.23)	
$\Delta \ln RAB_{i(t-3)}$	0.243 (0.419)	
$\Delta \ln KH_{i(t-1)}$		0.112 (0.84)
$\Delta \ln KH_{i(t-2)}$		0.154 (1.10)
$\Delta \ln KH_{i(t-3)}$		0.066 (0.49)
$\Delta \ln FERT_{i(t-1)}$	−0.006 (−0.50)	−0.006 (−0.56)
$\Delta \ln FERT_{i(t-2)}$	0.017 (1.38)	0.016 (1.34)
$\Delta \ln FERT_{i(t-3)}$	0.022** (1.96)	0.023** (1.98)
$\Delta \ln GCA_{i(t-1)}$	0.064 (1.13)	0.051 (0.92)
$\Delta \ln GCA_{i(t-2)}$	0.004 (0.06)	0.021 (0.36)
$\Delta \ln GCA_{i(t-3)}$	−0.074 (−1.33)	−0.078 (−1.41)
$\Delta \ln RAIN_{i(t-1)}$	−0.030 (−1.57)	−0.026 (−1.29)
$\Delta \ln RAIN_{i(t-2)}$	−0.046** (−2.23)	−0.040* (−1.88)
$\Delta \ln RAIN_{i(t-3)}$	−0.028 (−1.51)	−0.025 (−1.30)
Constant	−0.003 (−0.81)	−0.002 (−0.57)
D_{HILL}	−0.013* (−1.75)	−0.018** (−2.19)
Adj. R^2	0.264	0.236
F-Stat	11.455***	11.16***
DW	2.029	2.015

Note: ***, ** and *stands significance at the 1%, 5% and 10% level. T-statistics are in brackets; We used Eviews8 for all analysis.

years directly or indirectly cannot affect much the current period changes in yields or productivity. Only, through water uncertainty (that may be due to rising changes in precipitation) it could have short run adverse impact and that is reflected in the coefficient of two year lagged changes in rainfall. Hill dummy is found to have negative coefficient, which is in line with the earlier observation of backward diversification towards inferior crops. Due to uncertain water availability, backwardness in terms of use of modern agricultural inputs, machinery and access to capital the hill areas were found to lag behind the other regions of Assam in terms of attainment of productivity and diversity of crop (De and Bodosa, 2015) Coefficient of changes in lagged fertiliser application is positive and significant and the coefficient declines in the recent previous period changes.

Concluding Remarks

Unlike crop specific study in the existing literature, this study tried to see the overall impact of the climatic variables on Composite Productivity of agriculture using panel cointegration analysis. The overall agricultural productivity is found to be adversely affected by the growing temperature in the long run and also with some uncertainty in the short period. Though there exists short run uncertainty about the impact of rainfall, in the long run with appropriate adjustment in land allocation towards various crops, rainfall is found to be profitably utilised (hence positively related) to improve the overall productivity. Fertiliser, an important component of *Green Revolution Technology* is found to be an essential item for increasing agricultural productivity as desired in order to fulfil the need of food security.

It is therefore implicitly revealed that just increase in area under cultivation or cropping intensity is not enough unless it is supported by other necessary factors. Here it is found in general that though in very short period coefficient of GCA is insignificant, in the long run area expansion significantly reduce the overall productivity. It is of course not a guarantee of decline in total output as the marginal land also contributes some output with less productivity. It is quite natural that after utilisation of relatively more productive land, farmers go for less productive land (but productivity is expected to be greater than unit cost to generate at least some profit) to utilise the available excess labour, despite the prevalence of diminishing return to land. The result obtained therefore provides a consistent picture of overall and long run impact of climate change on the overall agricultural productivity in a climate sensitive sub-Himalayan part of India. The short term weather extremes would however have uncertain consequences.

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