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Climate change and food security in EAC region: a panel data analysis

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Abstract

Purpose – This study aims to analyze the impact of global climate change on food security in the East African Community (EAC) region, using panel data analysis for five countries, over 2000-2014.

Design/methodology/approach – The determinants of food security are expressed as a function of rainfall, temperature, land area under cereal production, and population size. The paper used pooled fixed effects to estimate the relationship among these variables.

Findings – Findings show that food security in EAC is adversely affected by temperature. However, precipitation and increasing areas cultivated with cereal crops will be beneficial to ensure everyone's food security.

Originality/value – Actions for mitigating global warming are important for EAC to consolidate the region's economic, political and social development/stability.

Keywords Climate change, Panel data analysis, Food security, EAC

Paper type Research paper

1. Introduction

Putting an end to hunger and malnutrition is considered to be a serious challenge for achieving sustainable development in developing countries. For instance, about 500 million people who are food insecure are still in Africa and Southern Asia. In addition, a high percentage of those people are directly or indirectly dependent on agriculture [Food and Agriculture Organization of the United Nations (FAO), 2015].

The Intergovernmental Panel on Climate Change (IPCC), in its fifth assessment report, remarks that climate change is negatively affecting crops, livestock, and fisheries. Also, climatic variability is threatening the agriculture sector and food security through the loss of rural livelihoods, the loss of marine ecosystems, inland water ecosystems, and the breakdown of food systems (IPCC, 2014). For example, disasters that hit tropical areas destroy the stability and food security of communities living there. Therefore, these tropical zones often witness food insecurity crises; especially that agriculture sector in these regions employs from 30 to over 80 per cent of the population (FAO, 2015).

In the IPCC's fourth assessment report, the agriculture sector in Africa was expected to experience periods of prolonged droughts and floods. Consequently, there would be reduction in the fertile agricultural land, expansion of arid/semi-arid land, and vast decrease

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in the productivity of fisheries (IPCC, 2007). In recent years, drought and elevated temperatures, as evidence of climate change, have adversely affected all the agricultural sub-sectors in the Horn of Africa and other African regions. As a result, estimates of the prevalence of severe food insecurity in the whole African Region is increasing, particularly for middle and eastern Africa (FAO, 2017).

With respect to FAO (1996), food security is attained when:

> [. . .] all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Thus, food security concept encompasses four main dimensions: food availability, economical and physical accessibility, utilization and stability. Accordingly, not only enough food being produced worldwide is needed but also everyone should have the ability to timely get this food, in the proper quantity and quality.

The East African Community (EAC) is a regional intergovernmental organization of six Partner States: Burundi, Kenya, Rwanda, South Sudan, Uganda and Tanzania. Through this community, these members cooperate together in political, economic, and social fields. They established a Customs Union in 2005, then a Common Market in 2010. In 2013, The East African Monetary Union (EAMU) Protocol was signed and set the ground for a monetary union within 10 years. Finally, in 2017, the EAC Heads of State agreed on reaching Political Federation by carrying out the Political Confederation as a transitional phase (EAC, 2017).

In spite of having a big capacity to produce enough food for its population, the EAC region frequently suffers from food shortages and hunger. There are a lot of factors that stand behind such a critical state, such as:

- prevalence of rain-fed farming systems;
- inadequate food access among the vulnerable and poor population;
- frequency and severity of global warming impacts on food production;
- modest prices paid to food producers;
- social unrest and political instability; and
- poor technologies applied by farmers (EAC, 2011).

Still, empirical studies that assess impacts of global climate change on food security in African regions like EAC are limited. Such research is needed by policy makers to design agricultural policies that can adapt to climate change and ensure food security simultaneously (Mendelsohn, 2009). Thus, this paper tries to estimate the relationship between food production and different climate-change factors (namely precipitation and temperature) in EAC States. It also tries to explore ways that enable the adaptation of agriculture sector in these countries to climate change and mitigate the effect of this change on food.

The rest of this study is organized as follows. Section 2 presents a literature review on the various impacts of global warming on food security in both developed and developing countries. Section 3 illustrates facts on relationship between climate change and food security in EAC. Sections 4 and 5 show the methodology, data sources, and the diagnostic tests used. Section 6 provides the empirical results. Finally, Section 7 concludes the paper.

2. Literature review

Recently, the impacts of climatic variability on food security have become debatable. Many researchers have analyzed this relationship empirically and consequently mixed findings have been reached. Some studies have indicated that climate change has a negative impact on agricultural production, food availability, and could result in food insecurity. While others have reported that positive and negative impacts of climate change may occur on different crops. Therefore, according to the latter group, the adverse effect of climate variability on food security is inconclusive (FAO, 2008). Thereby, this section reviews empirical studies carried out in this field, in both developed and developing countries, by giving details on the main variables and findings.

In Africa, some studies investigated empirically the relationship between climate change and food security in North and East Africa. For example, in Kenya, Kabubo-Mariara and Kabara (2015) estimated the effects of climate change on food insecurity for the period (1975-2012). The paper focused on the food availability, as one of the main dimensions for food security, of four major food crops; maize, beans, sorghum and millet. Results showed that food insecurity would get increased by climate change. In addition, climate variables had a non-linear relationship with food insecurity. For example, increased seasonal precipitation was associated with reduced food insecurity, but excessive precipitation would increase insecurity as this might damage the crops. In Tunisia, Ben Zaied and Zouabi (2015) estimated the long run impact of climate variability on olive crop in Tunisia, using data for 24 regions from 1980 till 2012. Empirical results showed that temperature increase and rainfall shortages had negative long-run effects on olive production, across regions, over the last three decades.

In Ethiopia, Geffersa (2014) investigated the impact of climate change on households' food security in 15 Ethiopian villages in rural areas, over the period (1994-2009). The empirical results indicated that climate change negatively and significantly affected food security through time. Findings also assured that other elements, such as land and livestock, could play an essential role in guaranteeing the households' food security. Also, Hagos *et al.* (2014) analyzed the impact of weather variables on the children under nutrition in Ethiopia, through the period (1996-2004). The study collected data on rainfall, temperature, children stunting, wasting, and underweight for three different zones. Results showed that for a given area, child stunting and underweight were positively affected by rainfall and temperature. However, wasting was found to be insignificantly affected by the climatic factors. Furthermore, Demeke *et al.* (2011) analyzed the effect of rainwater variation on food insecurity for rural households in Ethiopia, over the period (1994-2004). Results showed that food security and vulnerability were significantly affected by the level and variability of rainfall. In addition, there was a range of other factors (e.g. household size and livestock ownership) that could positively affect food security in Ethiopia.

With respect to the continent of Asia, some papers measured the impacts of climate change variables on food security there. For instance, Tokunaga *et al.* (2015) studied empirically the impact of global warming (measured by temperature, solar radiation, and precipitation) on Japan's agricultural production (rice, vegetable, and potato) using data for 8 regions in Japan throughout the period (1995-2006). By applying both static and dynamic panel data analyses, the study found that the rice production in Japan was reduced by the falling solar radiation while the vegetable and potato production were reduced by rising temperatures and precipitation. In addition, Wang (2010) measured the impact of climate change on food security, by using a sample of 27 provinces in China, for the period (1985-2007). The empirical findings indicated that the rural per capita food consumption was adversely affected by the agricultural disaster area, as a proxy for climate change. Therefore, climate change would lead to a shortage in food supply and consequently could have a negative impact on the food security in China.

Also, Arshed and Abduqayumov (2016) measured long-run impact of climate change on the productivity of both wheat and cotton in 12 major districts of Punjab, for the period (1970-2010). The study used annual temperature and average rainfall as proxies for climate change. The results showed that cotton productivity was positively affected by increasing temperature while wheat productivity was positively impacted by increasing precipitation. While in Iran, Kordi *et al.* (2015) measured the effects of average annual temperature and total annual rainfall, as proxies for climate change, along with other variables (fertilizers, seeds, machinery and labor) on wheat production. The study used data for 11 provinces from 1991 till 2011 to estimate its model. The results showed that there was a non-linear relationship between climate change variables and wheat production in Iran. For example, temperature had a positive effect on wheat yield before the maximum annual temperature and then had a negative effect. Moreover, in India, Kumar and Sharma (2013) studied the impact of climate change on both agricultural production and food security in India. The paper collected data for 13 states through the period (1980-2009). Regression model showed that both agricultural production and state-wise food security index composed in this study were negatively affected by climatic fluctuations Finally, for a sample of 71 developing countries all over the world, Badolo and Kinda (2014) investigated the nexus between climatic variability and food security. This model has traced the influence of climatic variability on food security and succeeded in analyzing the causal relationship between these variables for 71 developing countries. Due to the limited availability of data that are needed to compose food security index in developing countries, the model has chosen the ratio of undernourished people and food supply alternatively as proxies for food security index. Rainfall, arable land, land under cereal production and food prices were the main explanatory variables included in their model. This study was carried out over the period (1960-2008). Empirical findings showed that global warming reduced the food supply and increased the percentage of undernourished people in these countries. However, this negative impact was higher in Sub-Saharan economies than for other developing ones. Also, the negative effects of climate change were intensified by the outbreaks of civil wars and vulnerability to food price shocks.

3. Food security and climate change in East African Community

In EAC region, the water sector has been adversely affected by global warming. For instance, scientists have observed a rise in EAC lakes' deepwater temperature, besides lake-level fluctuations and volatility, since the 1960s. Also, the region witnessed periods of severe drought and rainfalls in late 1997. Moreover, flow of some rivers in the area has started to decline due to shortages in regional rainfall. For example, the Pangani Basin, which is inhabited by approximately 3.7 million people, is considered to be one of Tanzania's most prominent regions in agricultural and hydropower production. Because of raising temperatures and lessening rainfalls during dry months, the annual flow of River Pangani may be reduced by 6-9 per cent (IPCC, 2007).

Also, the region has gone through temperature increase and precipitation decrease recently. This has adversely affected long-cycle crops (such as sorghum and maize) and consequently led to significant shortage in food supply (WWF-Worldwide Fund for Nature, 2006). Additionally, EAC countries have been threatened by the devastating impacts of climate change on their agriculture; as they have been frequently hit by weather-related food emergencies (FAO, 2005).

Furthermore, climate change has negative effects on livestock and fisheries in EAC area. For instance, the "cattle corridor" in Uganda was hit by prolonged and severe drought in 1999/2000. This has led consequently to a big loss in animals, drop in milk production, increase in food prices, food insecurity, and sharp decline in economic growth [United Nations Framework Convention on Climate Change (UNFCC), 2007]. Besides, scientists have observed that the productivity of fisheries in the region has decreased over the past 200 years. This is due to climatic impact on lakes' ecosystems that has caused a decline in fish abundance in East African lakes (Roessig *et al.*, 2004).

As climate change is threatening the quality and availability of the region's resources, in 2010, EAC countries developed the EAC Climate Change Policy to guide their governments and other concerned groups on adaptation and mitigation actions to address climate change. This policy assured that goals of food security and economic development could not be attained without considering mitigation and adaptation measures to climate change in the area. Thus, with respect to adaptation, the policy focused on consolidating meteorological services, developing early warning systems, improving irrigation and protecting vulnerable ecosystems (such as wetlands, coastal, marine and forestry ecosystems). Concerning mitigation measures included in this policy, they were as follows: increasing pro-environmental energy resources, applying efficient crop and livestock production system, capturing opportunities in emission reductions, and engaging in reforestation in the region (EAC, 2010).

Moreover, the EAC countries tried in 2011 to achieve food security and rational agricultural production across the region, by applying the EAC Agriculture and Rural Development Policy. By focusing on increasing agricultural production, processing, storage and marketing, this policy aims at eradicating poverty and ensuring food security within the region (EAC, 2011).

In 2015-2016, Eastern Africa witnessed huge losses in the production of crops and livestock as it was severely affected by El Niño–Southern Oscillation[1]. As a result, the number of people suffering from undernourishment in the region increased from 121.4m to 132.2m; most of them were in Kenya and Uganda. In 2017, due to worsening climatic conditions, eastern Kenya, South Sudan and Uganda were hit by recurrent drought that destroyed major crops and raised food prices in these countries (FAO and ECA, 2018). Subsequently, in June 2018, a meeting was held by the regional East African Climate Change Technical Working Group, the GIZ Global Carbon Markets Programme, and the UNFCCC Regional Collaboration Centre. This assembly discussed ways for funding climate change mitigation and adaptation actions in EAC region, through global carbon markets and climate finance agreements (Namande, 2018).

4. Empirical analysis

4.1 Empirical model

As previously illustrated in the literature review section, Badolo and Kinda (2014) has succeeded in analyzing the causal relationship between climatic variability and food security for 71 developing countries. Later on, some papers have adopted the same model to study climate change impacts on food security in African countries (Kinda, 2017; Singh, 2018). However, the main shortage of this model is that it has not studied the four dimensions of food security. This has been due to the limited availability of data that are needed to compose food security index in developing countries.

Our paper has adopted the same framework, with some modifications in both dependent and explanatory variables due to some data limitations[2]. Thus, the following single multivariate equation is used to examine the relationship between food security in EAC and both climatic and non-climatic factors over the period (2000-2014):

$$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it} \quad (1)$$

With X_{it} the matrix of explanatory variables (precipitation, temperature, population growth and land under cereal production), in a country i at the period t. α_i comprises unobserved country-specific effects and ε_{it} is the error term. Y_{it} is the food production index (FPI) as a proxy for food security[3].

4.2 Data sources and variables description

The data range used in this paper starts from 2000 till 2014 for the five countries in EAC: Burundi, Kenya, Rwanda, Tanzania and Uganda[4]. This data range has been chosen to get balanced panel data for our model. The annual data on food production index, precipitation, temperature, population growth and land under cereal production are obtained from Climate Change Knowledge Portal and the World Development Indicators Database; both provided by the World Bank (World Bank, 2018a, 2018b).

Food production index (FPI), by covering food crops that are edible and contain nutrients [5], calculates the changes in the production of food in a given year relative to the base year (Index Mundi, 2018). Population growth (PG) is the annual growth rate in population size while land under cereal production (LC) is measured in hectares. With respect to climatic factors, precipitation (P$recip_t$) is measured in millimeter and temperature (Temp_t) is measured in Celsius degree centigrade[6]. Data on these variables are converted into natural logarithms (except for PG) to facilitate the estimation procedure. The descriptive statistics, mean value, standard deviation and coefficient of variation of these variables are given in Table AI.

5. Post regression diagnostic tests

Our model has been estimated with *EViews 10*. Choice has been made among fixed effects (FE) and random effects (RE); as they represent the two alternative methods in our case for estimating static panel models. Tables AII and AIII show the results of each one of them. It is worth noting that Pooled OLS method hasn't been used as it does not account for the unobserved heterogeneity of countries. On the other hand, FE (Table AII) and/or random effects (Table AIII) estimators have successfully addressed this problem (Baltagi, 2005)[7]. Therefore, decision should be made whether to rely on FE method or RE method. Accordingly, Hausman test has been used and it shows that the FE method is more suitable than the random effect method for our model (Table AIV)[8].

To identify the cross sectional independence in panel data set, Pesaran's test shows that there is no cross-section correlation in residuals of our model (Table AV). Also, Jarque-Bera normality test assures the normality of errors at 5 per cent significance level (Figure 1). With respect to serial correlation (autocorrelation), Durbin-Watson statistic value shows that there is a first-order autocorrelation. Finally, Tables AVI and AVII show that the model suffers from heteroskedasticity. So, to deal with the problems of heteroskedasticity and serial correlation, *White period method* is used in re-estimating our FE regression model (Table AVIII)[9].

6. Results

Table AVIII shows that climatic factors – compared to non-climatic factors – play major role in determining food security in EAC region as both rainfall and temperature have significant impact on our dependent variable while land under cereal production is the only non-climatic variable that has a significant effect.

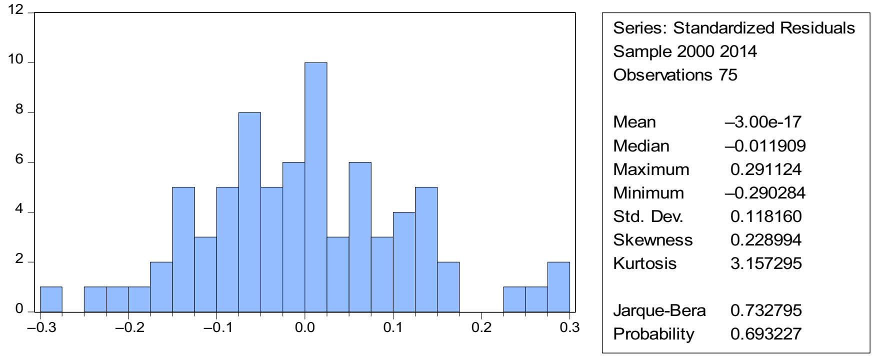

Figure 1.
Results of normality test

Regarding the specific impact for each one of the climatic variables, results indicate that rainfall has a positive effect; food security may go up by 0.32 per cent due to 1 per cent increase in annual precipitation. On the contrary, temperature has a negative impact; food security decreases by 2.16 per cent due to 1 per cent increase in annual temperature. The positive impact for precipitation can be justified by the fact that rainfall is an important source of agriculture in EAC countries. As rain-fed agriculture is widespread in East Africa, any increase in rainfall might cause an increment in agricultural/food production, households' incomes and food security. With respect to temperature, its sign shows that temperature variability adversely affects agricultural production. Consequently, the economic growth rates of these countries will fall and they will have limited ability to import food. Hence, this can lead to a shortage in the national food supply and an increase in food insecurity as Dell *et al.* (2008) show. This implies that changing temperature patterns could be a threatening source for attaining food security in EAC countries.

With respect to non-climatic variables, findings show that land under cereal production has a positive and significant effect on food security; every 1 per cent increase in land area harvested with cereals may raise food security by 0.32 per cent. This agrees with findings of Barrios *et al.* (2008). Hence, increasing the lands cultivated with cereal crops will increase directly the crop production and availability, whereby the national food supply and security will increase. Thus, agricultural policies that encourage the use of lands for cereal cultivation increase food supply and security. Also, there is an insignificant impact for population growth on our dependent variable. Therefore, claims of Neo-Malthusian economists (Ehrlich and Ehrlich, 1991) that population growth could exert a high pressure on agricultural resources, negatively affect agricultural productivity and reduce food supply, does not apply to EAC area.

7. Conclusion

This paper analyzes the effects of climatic variability on food security for EAC region, over the period (2000-2014), using panel data. The estimation results show that rainfall has a positive and significant impact on food security in the region while temperature has a negative and significant effect. Hence, increase in rainfall might cause an increment in food production and food security while changing temperature patterns could be a challenge for attaining food security in EAC countries. Also, findings indicate that there is an insignificant impact for population growth on our dependent variable whereas land under cereal production has a positive and significant effect. Thus, increasing the lands cultivated with cereal crops will increase directly the crop production and availability, whereby the national food supply and security will increase.

Therefore, some measures can be undertaken to alleviate hunger and food insecurity in EAC region:

- adopting agricultural techniques that improve food production in EAC countries should be adopted;
- activating effective mitigation programs that improve rural households' ability to cope with climate change;
- increasing investments in agricultural research that focuses on reducing losses in food production due to climate variability;
- diversifying the economic structure for EAC members to alleviate the adverse impacts of climatic shocks in these countries; and
- ensuring efficient use of both precipitation and land under cereal production, since they positively affect food security in the region.

For example, EAC governments can encourage rainwater-harvesting systems, provide rainwater storage facilities and improve rainwater infiltration into soils. Additionally, diversifying land use, enhancing vegetation cover and providing safe discharge of excess runoff water should be carried out to improve soil health and avoid its erosion.

Notes

1. The El Niño–Southern Oscillation (ENSO) is a climatic change that occurs every 2 to 7 years and lasts from 6 to 24 months. This phenomenon causes enormous increase in temperature in the tropical areas. Consequently, it leads to huge rainfall, droughts, forest fires, floods and other extreme weather events worldwide.
2. Due to limitations in data availability in our study, food production index has been used as a dependent variable instead of both the ratio of undernourished people and food supply. For the explanatory variables, precipitation and temperature have been the climatic variables, while population growth and land under cereal production have become the non-climatic ones.
3. As food security is a multidimensional concept, we chose FPI as an appropriate proxy for the availability dimension.
4. The Republic of South Sudan has not been included in the model as it has become a full member of EAC on 5th September, 2016.
5. In spite of being edible, coffee and tea are excluded from these crops as they have no nutritive value.
6. Time series data of precipitation and temperature were collected on monthly basis from the World Bank (climate change knowledge portal: http://sdwebx.worldbank.org/climateportal) and then converted to annual values for the period (2000-2014).
7. We have applied neither unit root nor cointegration tests, following remarks of Breitung and Pesaran (2005) and Park (2011) and that assure the inessentiality of carrying out these tests under the fixed/random effects.
8. It's worth noting that table 5 includes a warning message as follows: "estimated cross-section random effects variance is zero". Sueyoshi (2018) explains that this informative message just appears to assure that the RE estimates are the same as OLS in this case. Thus, it does not imply anything wrong with the estimation process.

9. The White period method presumes that the errors for a cross-section are serially correlated and heteroskedastic. Thus, estimation results given by this method are robust to autocorrelation and heteroskedasticity. For further details, refer to: IHS Global Inc.: *EViews 10 User's Guide II*, 2017.

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Appendix

	FPI	Precip	Temp	LC	PG
Mean	4.667741	4.453455	3.122232	13.87660	2.968856
Median	4.617889	4.524620	3.139125	14.31810	2.989028
Maximum	5.233512	4.827805	3.243256	15.68400	5.539102
Minimum	4.276805	3.620394	2.987724	12.08846	1.578337
Std. dev.	0.198325	0.277569	0.081508	1.158472	0.523865
Skewness	0.699387	−0.829952	−0.138456	−0.128281	1.019475
Kurtosis	3.404354	2.892082	1.589317	1.542564	9.844758
Jarque-Bera	6.625229	8.646654	6.458456	6.843577	159.4001
Probability	0.036421	0.013256	0.039588	0.032654	0.000000
Sum	350.0805	334.0091	234.1674	1040.745	222.6642
Sum Sq. dev.	2.910641	5.701281	0.491629	99.31228	20.30813
Observations	75	75	75	75	75

Table AI.
Descriptive statistics

Dependent variable: FPI
Method: panel least squares
Sample: 2000 2014
Periods included: 15
Cross-sections included: 5
Total panel (balanced) observations: 75

Variable	Coefficient	Std. error	*t*-statistic	Prob.
C	−0.298184	3.946728	−0.075552	0.9400
PRECIP	0.326112	0.114212	2.855317	0.0057
TEMP	−2.163719	1.197937	−1.806204	0.0754
PG	−0.025885	0.032279	−0.801915	0.4255
LC	0.745578	0.084113	8.863972	0.0000

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.645038	Mean dependent var	4.667741
Adjusted *R*-squared	0.602012	S.D. dependent var	0.198325
S.E. of regression	0.125116	Akaike info criterion	−1.206982
Sum squared resid	1.033167	Schwarz criterion	−0.928884
Log likelihood	54.26183	Hannan-Quinn criter.	−1.095941
F-statistic	14.99192	Durbin-Watson stat	0.987488
Prob(*F*-statistic)	0.000000		

Table AII.
Results of the estimation based on FE method

Dependent variable: FPI				
Method: Panel EGLS (Cross-section random effects)				
Sample: 2000 2014				
Periods included: 15				
Cross-sections included: 5				
Total panel (balanced) observations: 75				
Swamy and Arora estimator of component variances				
Variable	Coefficient	Std. error	*t*-statistic	Prob.
C	0.797268	1.139374	0.699742	0.4864
PRECIP	0.386429	0.075996	5.084883	0.0000
TEMP	0.550960	0.245214	2.246853	0.0278
PG	−0.054086	0.028501	−1.897644	0.0619
LC	0.042509	0.014534	2.924803	0.0046
		Effects specification		
			S.D.	Rho
Cross-section random			0.000000	0.0000
Idiosyncratic random			0.125116	1.0000
		Weighted statistics		
R-squared	0.172405	Mean dependent var		4.667741
Adjusted *R*-squared	0.125114	S.D. dependent var		0.198325
S.E. of regression	0.185504	Sum squared resid		2.408831
F-statistic	3.645620	Durbin-Watson stat		0.336067
Prob(*F*-statistic)	0.009350			
		Unweighted statistics		
R-squared	0.172405	Mean dependent var		4.667741
Sum squared resid	2.408831	Durbin-Watson stat		0.336067

Table AIII. Results of the estimation based on random effects method

Test cross-section random effects				
Test Summary		Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random		87.879106	4	0.0000
**WARNING: estimated cross-section random effects variance is zero				
Cross-section random effects test comparisons:				
Variable	Fixed	Random	Var(Diff.)	Prob.
PRECIP	0.326112	0.386429	0.007269	0.4793
TEMP	−2.163719	0.550960	1.374924	0.0206
PG	−0.025885	−0.054086	0.000230	0.0627
LC	0.745578	0.042509	0.006864	0.0000
		Cross-section random effects test equation		
Dependent variable: FPI				
Method: Panel least squares				
Date: 08/09/18 Time: 22:27				
Sample: 2000 2014				
Periods included: 15				
Cross-sections included: 5				
Total panel (balanced) observations: 75				
Variable	Coefficient	Std. error	*t*-statistic	Prob.
C	−0.298184	3.946728	−0.075552	0.9400
PRECIP	0.326112	0.114212	2.855317	0.0057
TEMP	−2.163719	1.197937	−1.806204	0.0754
PG	−0.025885	0.032279	−0.801915	0.4255
LC	0.745578	0.084113	8.863972	0.0000
		Effects specification		
Cross-section fixed (dummy variables)				
R-squared	0.645038	Mean dependent var		4.667741
Adjusted *R*-squared	0.602012	S.D. dependent var		0.198325
S.E. of regression	0.125116	Akaike info criterion		−1.206982
Sum squared resid	1.033167	Schwarz criterion		−0.928884
Log likelihood	54.26183	Hannan-Quinn criter.		−1.095941
F-statistic	14.99192	Durbin-Watson stat		0.987488
Prob(*F*-statistic)	0.000000			

Table AIV. Correlated random effects – Hausman test

Periods included: 15
Cross-sections included: 5
Total panel observations: 75
Cross-section effects were removed during estimation

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	13.97599	10	0.1741
Pesaran scaled LM	0.889059		0.3740
Bias-corrected scaled LM	0.710488		0.4774
Pesaran CD	0.816267		0.4143

Table AV. Residual cross-section dependence tests

Table AVI.
Panel cross-section
heteroskedasticity

Null hypothesis: Residuals are homoskedastic			
Specification: FPI PRECIP TEMP PG LC			
	Value	df	Probability
Likelihood ratio	21.43678	5	0.0007
LR test summary			
	Value	df	
Restricted LogL	22.39848	71	
Unrestricted LogL	33.11687	71	

Table AVII.
Panel period
heteroskedasticity
LR test

Null hypothesis: Residuals are homoskedastic			
Specification: FPI PRECIP TEMP PG LC			
	Value	df	Probability
Likelihood ratio	40.39369	5	0.0000
LR test summary			
	Value		df
Restricted LogL	22.39848		71
Unrestricted LogL	42.59532		71

Table AVIII. Results of the estimation based on FE and white period method

Dependent cariable: FPI
Method: Panel least squares
Periods included: 15
Cross-sections included: 5
Total panel (balanced) observations: 75
White period standard errors and covariance (no d.f. correction)

Variable	Coefficient	Std. error	*t*-statistic	Prob.
C	−0.298184	3.463320	−0.086098	0.9316
PRECIP	0.326112	0.096636	3.374647	0.0012
TEMP	−2.163719	1.039589	−2.081322	0.0413
PG	−0.025885	0.016997	−1.522890	0.1326
LC	0.745578	0.101037	7.379269	0.0000

Effects specification

Cross-section fixed (dummy variables)

R-squared	0.645038	Mean dependent var	4.667741
Adjusted *R*-squared	0.602012	S.D. dependent var	0.198325
S.E. of regression	0.125116	Akaike info criterion	−1.206982
Sum squared resid	1.033167	Schwarz criterion	−0.928884
Log likelihood	54.26183	Hannan–Quinn criter.	−1.095941
F-statistic	14.99192	Durbin–Watson stat	0.987488
Prob(*F*-statistic)	0.000000		

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