Research Article

Does Endogeneity Undermine Temperature Impact on Agriculture in South Asia?

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Abstract | This study uses annual data for five South Asian countries for the period 1999 to 2014 to investigate the impact of temperature on agriculture controlling for potential endogeneity by using locality as an instrument. Unsurprisingly, the magnitude of temperature coefficient increases substantially when endogeneity is controlled and becomes significantly higher (6 percent to 13 percent) than the previously reported findings in the literature. The findings suggest that endogeneity is a crucial issue and must be controlled before carrying out an empirical analysis on the temperature-agriculture nexus to obtain reliable estimates of the regression coefficients. Policymakers should pay more attention to combat negative impacts of rising temperature. This will have an impact on the agriculture and hence on the livelihood of the mass population residing in South Asian countries.

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Introduction

The relationship between climate change and agriculture has been an interesting topic among researchers over the last few decades. Voluminous work across the world has been undertaken to investigate the impacts of climate change on agriculture (Hunt and Watkiss, 2011; Dasgupta et al., 2014; Babar et al., 2014; Javed et al., 2014; Bezabih et al., 2014; Rosenzweig et al., 2014; Porter et al., 2014). However, this empirical literature overlooks the potential problem of endogeneity that emerges from the possible feedback between agriculture and temperature as agriculture related activities significantly emit greenhouse gases (GHGs) that lead to global warming, and therefore making these estimates misleading. In addition, these studies suffer from the omitted variable bias (Auffhammer et al., 2011) as control variables like technological change and population are not included in the model.

Over one fifth of the world population resides in South Asia known as the most disaster-prone region in the world (UNEP, 2003). Due to its large agriculture base this region is highly sensitive to climate change that can inflict wide range of economic losses across different regions and sectors (Hunt and Watkiss, 2011). Because of high temperature, crop yield decreases while weed and pest production increases (Babar et al., 2014). Furthermore, climate change is a threat to water resources, vegetation, snow cover and human health (Malla, 2008). The overall impacts of climate change on agriculture are predicted to be harmful, intimidating global food security. In addition, twenty-first century temperature projections for South Asia suggest a significant acceleration of warming over that observed in the twentieth century that is the most pressing threat to the livelihood of more than one billion populations. Further about one fifth of the total GHG emissions come from agriculture related activities therefore, agriculture sector is required to contribute in reducing GHG emissions (FAO, 2016).

In this study we introduce an innovative instrument, locality - longitude and latitude for temperature to overcome potential problem of endogeneity while investigating the impact of temperature on agriculture in South Asia. We strongly believe that our novel instrument can affect agriculture only through the channel of temperature and not directly. In addition, the validity of the instrument is tested through weak identification and over identification tests. The use of location as an instrument is justified not because of its absence in previous empirical literature but due to its strong links with agriculture. This is an innovative tool as previous studies used other instruments instead of location. This instrumental approach also addresses the problem of measurement error that, if ignored, can result in biased estimates of the coefficients (Miguel et al., 2004). Our intensive review of literature could not find any study that addresses the reverse causality between the dependent and independent variables by using locational instrument. The endogeneity is an issue linked with regression analysis where independent variables may be correlated with the error term.

The climatic variations are expected to inflict wide range of economic losses across different regions and sectors (Hunt and Watkiss, 2011). Different models have been used to investigate the impact of climate change on agriculture like Crop Simulation Models, Production-Function Models, Ricardian Approach, General Equilibrium Models (GEMs) and the Integrated Assessment Models (IAMs), yet the full understanding of the impact is not comprehensive (Mendelsohn et al., 1996). For example, Crop Simulation Models studies provide only best guess (Wallach et al., 2006) as reliable data on soil property and management practices is not available. The widely used production function approach explicitly measures economic impacts of weather on agriculture. However, it does not take into account the adaptive behavior of farmers (Reilly et al., 1996). Ricardian models cater for this weakness by gauging weather effects on net revenues. However, this approach ignores transition cost (Sohngen et al., 2002) and makes unrealistic assumption of constant prices (Cline, 1996). According to Mount and Li (1994), this drawback of Ricardian model is addressed by models that rely on mathematical programming. Contrary to models discussed above, GEMs analyze climate change-agriculture nexus linking it with other sectors of the economy (Calzadilla et al., 2010). Nevertheless, these models are criticized for suppressing the spatial characteristics (Mendelssohn and Dinar, 2009). Currently, IAMs models are frequently in use (Kainuma et al., 2003) as they provide useful insights to the policymakers bringing information from different academic disciplines. These models are not free from criticism and also criticized for taking climate as an exogenous variable. In addition to above approaches panel data estimation techniques are also used in empirical literature that have some advantages on the previous models (McCarl et al., 2008). In the light of above discussion, the present study uses stochastic production function approach suggested by Just and Pope (1978) to estimate the effect of temperature on agriculture.

This research contributes to existing empirical literature at least in two ways. First the issue of endogeneity is addressed by introducing an innovative instrument that is expected to provide reliable estimates of the regression coefficients. Second this research uses agriculture value addition as dependent variable instead of crop production or revenue that are commonly used in previous empirical literature (Mendelsohn and Dinar, 2003) as it encompasses all agriculture related activities like livestock and fisheries that are also vulnerable to climatic variations.

Materials and Methods

Five South Asian countries namely Pakistan, India, Sri Lanka, Nepal, and Bangladesh are included in the sample due to their broad agriculture base and are highly vulnerable to climatic events that can directly affect the livelihood of millions of people through different channels. The time period of the study spans from 1999 to 2014. A total of 80 observations are available for the analysis in the panel setting. Agriculture value added is dependent variable in the model, taken from World Development Indicators (WDI), that is a net output from fishing, forestry, and cultivation of crops and livestock production measured in US$. Independent variables include average annual temperature, our variable of interest, obtained from Climate Research Unit (CRU), University of East Anglia, the UK. Fertilizer consumption, agricultural input imports (percent of merchandize imports), total population and agriculture land area are included as control variables that also come from WDI. Two locational coordinates - Latitude and Longitude - that determine the temperature of a location are used as instrument variable. The model of the study can be written in regression form as follow: (Equation 1)

$$Y_{i,t} = B_0 + \beta_1 T_{i,t} + \beta_2 F_{i,t} + \beta_3 AII_{i,t} + \beta_4 POP_{i,t} + \beta_5 ALA_{i,t} + \alpha_i + \gamma_t + \epsilon_{i,t} \;\ldots\ldots\ldots (1)$$

Where;

$Y_{i,t}$ is the agriculture value of i^{th} country at time t. T, F, AII, POP, ALA, stand for temperature, fertilizer, agriculture input imports, population and arable land area respectively. Equation (1) is estimated by using country fixed effect $\boldsymbol{\alpha} i$ to control country specific time invariant characteristics and year fixed effect γt is controlled for the shocks. $\epsilon_{i,t}$ is an unobservable error term with zero mean.

Results and Discussion

To avoid the risk of spurious regression, we first apply Levin, Lin and Chu (LLC) panel unit root test (Levin et al., 2002) devised to test variables for their stationarity. The following specification presented by Kula et al. (2009) for panel unit root test is used.

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{L=1}^{Li} \gamma_1 \Delta y_{i,t-1} + \epsilon_{i,t}$$

Where:

Subscript i and t stands for country and year respectively while $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$ and α_i, β_i and γ_1 are an intercept and coefficient to be estimated respectively. Li is the lag length to be determined by Schwartz or Akaike information criterion. Levin, Lin and Chu panel unit root test has the null hypothesis H_0: β = 0 for all i against the alternative H_1: β < 0 for all i. The results of unit root test are reported in Table 1 which shows that all variables are stationary at level, level and trend.

Table 1: *Results of the unit root tests.*

Variables	Individual effect	Individual effect Individual linear trend	None
Agriculture value added	-13.17***	-12.11***	-9.61***
Temperature	-89.09***	-86.74***	-7.64***
Fertilizer	-21.33***	-24.14***	1.64
Agriculture input imports	-7.84***	-9.68***	-6.94***
Population	-8.56***	-24.77***	-7.87***
Agriculture land area	-21.23***	-59.44***	9.77***

***, **, *: *Show null hypothesis of the presence of unit root is rejected with 99 percent, 95 percent and 90 percent confidence, respectively.*

Table 2 shows the mechanism of adding additional control variable one by one. Many environmental factors like, floods, sunshine, monsoon pattern, wind speed, humidity etc. can affect agriculture value addition. However, we include only temperature in our model as focus of the study is on how potential endogeneity problem can affect the results. Instead of environmental variables some other factors like agriculture inputs, agriculture land area, fertilizers and population are included as control variables. First and last columns of table show restricted and full model

Table 2: *Regression results after controlling for additional control variables.*

Variables	Temperature (1)	Fertilizer (2)	Agriculture Inputs Imports (3)	Population (4)	Agricultural Land (5)
Temperature	-0.21*	-0.24*	-0.29*	-0.31**	-0.37***
Fertilizer		-0.05	-0.09	0.09	0.12***
Agriculture Input Imports			0.33**	-0.34*	0.42**
Population				0.73*	0.77**
Agriculture Land Area					0.43*
Addjusted R^2	0.11	0.13	0.14	0.46	0.52
Observation	80	80	80	80	80

***, **, *: *Show significance level at 99%, 95% and 90% respectively.*

Table 3: *Instrumental variable (IV) first stage and second stage results.*

Panel A: IV First Stage	Full Sample	Pakistan	India	Srilanka	Nepal	Bangladesh
Longitude	-0.043*** (0.001)	-0.091*** (0.005)	-0.067*** (0.016)	-0.031 (0.041)	-0.120*** (0.031)	-0.052*** (0.009)
Latitude	-0.072** (0.042)	-0.123*** (0.013)	-0.091* (0.002)	-0.017*** (0.003)	0.113*** (0.009)	0.050 (0.121)
Constant	3.465 (4.323)	22.321*** (7.244)	11.201 (12.633)	11.231 (7.267)	9.724*** (4.271)	3.605 (53.509)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.226	0.385	0.484	0.367	0.401	0.289
F-Statistics	21.93	74.54	32.16	74.21	14.85	93.78
Observations	80	16	16	16	16	16
Panel B: IV Second Stage						
Temperature	-0.047*** (0.002)	- 0.102*** (0.025)	-0.072*** (0.013)	-0.033*** (0.004)	-0.137*** (0.003)	-0.055*** (0.013)
Constant	4.176*** (1.143)	14.132*** (3.401)	10.219 (9.71)	5.604*** (1.726)	23.022*** (3.290)	-17.192*** (4.083)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.521	0.645	0.591	0.495	0.364	0.459
Wald Chi^2	2156	1724	1375	9641	7893	376
Observations	80	16	16	16	16	16

Note: *Regressions control for fertilizer, agriculture input imports, population and agriculture land area. Temperature is instrumented with geographical coordinates (Longitude and Latitude). ***, **, *: Show significant at 1 percent, 5 percent and 10 percent respectively. Robust standard errors are reported in parenthesis.*

respectively. It is evident that in full model, variables are statistically significant with sufficiently large value of the adjusted R^2. Temperature coefficient shows systematic improvement with the addition of each new variable in the model. Temperature has negative sign while all control variables have positive sign which are according to the prior expectation and fully supported by empirical literature.

Due to potential problem of endogeneity, regression is re-estimated by instrumental variable two stages least square (IV-2SLS) where locality instrument is used that is substantially correlated with temperature and can influence agriculture only through temperature. IV method is applied when independent variable of interest is correlated with the error term because under such conditions OLS method is not capable of delivering consistent parameter estimates. This method enables researchers to get consistent estimators in the presence of correlation between an explanatory variable and error term in a regression model. The availability of more than one instrument for a single explanatory endogenous variable can lead to different IV estimates and qualitative conclusion that is not a very attractive possibility. 2SLS method has been developed to overcome this problem. It combines several instruments to produce a single instrument needed to implement IV for regression equation (Wooldridge, 2008).

The results of both stages (stage 1 and 2) are reported in Table 3. Endogeneity test rejects the null hypothesis of "variables are exogenous" with ($p<0.01$) which supports the use of 2SLS as it takes endogeneity issue into account. Results show that instrumental variables have positive sign and are statistically significant, therefore, can be substituted as an instrument for temperature. First, results reported in Table 2 are discussed and then based on the relevancy and importance from research and policy point of view only stage 2 (Table 3) results are elaborated.

Our discussion starts with the control variables that are all positively linked with agriculture value addition. Table 2 reveals that fertilizer is significant predictor of agriculture value addition with its positive impact that is according to the prior expectations and several previous findings support this result. For instance, Javed et al. (2014) reported that use of fertilizer is a key determinant of increase in agriculture production in Pakistan. Unlike the role of fertilizer in context of agriculture researchers are divided on the relationship between population and agriculture output. Our results that population has significant positive impact on agriculture is mostly in line with previous studies. However, few researches find the opposite impact of population on agriculture. Malthusian doctrine predicts negative impacts of population while Panayotou (1994) reports the positive role of population through intensive use of labor and institutional changes. Numerous other studies highlight positive association between population growth and agriculture (Templeton and Scherr, 1997). Findings reveal that import of agriculture inputs, mechanical as well as non-mechanical, enhances the agriculture value addition in South Asia which supports Dorward et al. (2004) view of positive role of state interventions at different stages of agriculture market development. The role of arable land area in context of climate change-agriculture nexus is confounding. Increase in arable land area is expected to increase crop production and at the same time GHG emissions will also increase because of increased agriculture activities that will impact agriculture negatively. Therefore, the positive impact of increase in arable land area may outweigh the negative impact of GHG emissions on agriculture which provides justification for the inclusion of this variable in regression model. Arable land area is positively linked with agriculture variable in our analysis which is supported by Javed et al. (2014) who found a significant positive relation between cultivated area and agriculture production.

After a brief discussion of control variables now we turn focus on core variable of interest, that is, temperature. Strong negative impact of climate change is evident from Table 2. The rising temperature can affect agriculture negatively through different channels (Dell et al., 2012). Many studies report negative impact of temperature on agriculture (Bezabih et al., 2014; Li et al., 2015; Jascha et al., 2015) that is in line with our findings. However, a few studies reveal that rise in temperature has positive impact on agriculture productivity (Babar et al., 2014; Hussain and Mudasser, 2004). It is interesting to note that the coefficient of temperature swells in magnitude as the instrument is introduced to handle potential threat of endogeneity (see second stage results in Table 3) which means the previous empirical findings need to be re addressed. In the whole panel, the coefficient increased by 9 percent that is a substantial increase from all respects. Controlling for country and year fixed effects, it is observed that the more a country is dependent on agriculture, the more it is vulnerable to temperature variations. For example, the temperature coefficients scale up by 13 percent, 12 percent and 7 percent respectively in case of Nepal, Pakistan, and India while it improves only by 6 percent in case of Sri Lanka and Bangladesh. Sectoral share of agriculture in gross domestic product is highest in Nepal followed by Pakistan and India, therefore, the negative effect of temperature on agriculture is higher in these countries as compared to Bangladesh and Sri Lanka. We conclude that the negative impact of temperature rise estimated previously are questionable and need to be readdressed after controlling for endogeneity.

Instrumental variable should be valid to ensure reliability of findings therefore we conduct some diagnostics test at the end. The significantly high value of the F-statistics (F=88.14) is greater than all the critical values obtained under 2SLS (first stage) which means instruments are not weak. The correlation between temperature and its instrument is as high as 0.76 another evidence of a good instrument. Finally, the very small values of the Sargon score (0.001) and Basman Chi-Square (0.040) rule out the issue of over identification. In the end we mention some of the caveats of the study. First, the coordinates of the capital city used in the study as an instrument are not true representative of the country; however, being the first study of this nature, it provides food for thought for future researchers. Second, other environmental variables like monsoon pattern, floods, wind speed and sunshine are not included in the regression despite their relevance with agriculture as the main objective of the study is to empirically show that when the problem of endogeneity is controlled, the magnitude of the effects of temperature on agriculture increases.

Conclusions

The primary objective of this study was to gauge the impact of temperature on agriculture in south Asia for the period 1999-2014 by controlling potential problem of endogeneity to obtain more reliable estimates of the regression coefficients. The study finds that temperature is going to impact agriculture negatively in the region and these impacts become larger (6 percent to 13 percent) when the issue of endogeneity is properly addressed. This may be due to the inclusion of control variables and introduction of locality as an instrument. The behavior of the control variables is according to empirical literature. The study provides strong implications for the policymakers to confront rising temperature that is an impending danger to agriculture. For example, drastic and immediate measures need to bring in practice to combat negative impacts of temperature depending upon the socio-economic and geo-political dynamics of the country. Farmers need to be informed and empowered to combat rising temperature to make agriculture sustainable. Subsidies on inputs, diversification of livestock species and adaptation of new weather resilient crop varieties could be few options that are available with the farmers.

Conflict of Interest

The authors do not have any conflict of interest.

Authors' Contribution

Muhammad Iftikharul Husnain: Contributed by writing abstract, introduction, results and discussion sections of the paper.
Aneel Salman: Collected data and carried out analysis.
Inayatullah Jan and Tahir Mahmood: Contributed in discussion, conclusion, language editing and formatting the paper.

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