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Research & Development Expenditures and Climate Change Impact on Maize Productivity: A Case Study of Pakistan, China and India

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Abstract

The current study is undertaken to empirically analyse the contribution of Research and Development expenditures on the productivity of maize crop in Pakistan, India and China. We employed an innovative panel data methodology PMG to estimate the impacts of R&D expenditures and other climatic variables on the productivity and yield level of maize crop in the mentioned countries. We found that R&D has significant contribution in increasing productivity in all these countries and the crop yield have been positively affected by R&D expenditures. However, the marginal contribution varies across different countries. Marginal contribution of R&D expenditure is high in Pakistan which sheds light on the importance of R&D on alleviating most of our agricultural issues. The climatic factors though have shown mixed effect but in case of Pakistan their negative effect is low as the threshold level of these factors for adverse effects are not crossed yet. Timely management and R&D on these issues can save agriculture from devastating effects of climate change factors. Research should focus on drought tolerant varieties with high potential. Social scientists should work on how to increase the adoption of new and innovative technologies for high yield agriculture. Communicating cost benefit studies to farmers can enhance their confidence of adopting the high-cost agricultural technologies.

Keywords: R&D, Innovations, Maize, Yield, Climate Change, Rainfall, Temperature

Introduction

An important consideration of the agriculture sector is the increased crop productivity, as Romer (1990) reported that the return to public R&D expenditures is significantly high and to stimulate the productivity growth rate R&D is a direct and simple way. In available literature recently a large body have reported that R&D is an influencing factor of output growth. In theoretical and empirical both models cumulative R&D has been incorporated as the main engine of innovation, technological development and per unit productivity growth.

Pakistan economy has been long labelled as "an agricultural country" by all national and international literature and policy analysts as it is evident from the latest Pakistan Economic Survey (2020-21) where 38.5% labor force is earning their livelihood in agriculture sector. But when it comes to contribution of this sector in total GDP, it shows an alarming contradictory statistic as only 19.2 percent of agriculture sector contribute to the total national output compared to industrial sector's 19.12 and services sector's 61.68 percent. Maize is third important serial crop after wheat and rice for Pakistan and for other sampled countries. Maize production was 8,465 thousand tones cultivated on an area of 1418 thousand hectares. Although, maize production and area both increased over time but, the overall agricultural sector statistics shows a clear evidence of Pakistan's agriculture sector deteriorating contribution and can be considered as a major obstacle in economic growth. Climate change is an important maize crop determinant and the developing economies are at high risk. Yield losses are higher in the presence of drastic fluctuations in rainfall pattern and temperature variations (Shoko et al., 2019). As the modern world had experienced a significant contribution of R&D in growth of agricultural during the last few decades and more specifically over the past twelve years. Reduced agricultural research and development by international

organizations and public sector in developing countries may have contributed to the slowing growth in crop yield (Massuanganhe, 2008). Kumar and Mittal (2009) outlined that the R&D in agriculture has the potential to mitigate the problems of agriculture sector for the long-term.

Pakistan is in dire need of uplifting the agriculture sector for provision of food for growing population, inputs contribution to domestic secondary and tertiary sectors, increased domestic and export earnings with eventual improvement in overall welfare. All this can be achieved through endogenous treatment of technology and research and development (R&D) in agriculture sector. A sustainable higher maize productivity may help in achieving food security and reduced poverty in Pakistan and in other developing economies.

Significance of the Study

Food security has been under the threat of several interconnected factors such as population growth, environmental problems, and land degradation (Chandio et. al., 2021). Among all these, climate change is an important factor of supply shock. Maize is considered as an important staple crop and third leading crop after wheat and rice. Scientist have been successful in developing new maize varieties that have shown high potential. This study contribute to the literature about the importance and impact of R&D expenditures for informed policymaking. This will help in proper allocation of funds for mitigating the climate shocks and increasing maize production. This research study is the first attempt to analyse the role of innovation in maize production for Pakistan. The paper also compares the marginal return of the R&D with neighbouring countries by employing a newer econometric methodology, Pooled Mean Group (PMG) or Panel ARDL.

Theoretical Framework of the Study

In this study, we will test the endogenous growth theory of Romer (1988) based on three premises. Firstly, technological improvements increases output per worker and provide incentive for capital accumulation. Secondly, technological improvement/change comes in response to market incentives and government grants to academic research to create new knowledge and instructions to increase product value. And third premise is that newly developed knowledge and instructions can be taken as initial fixed costs and can be used over and over again. However, here in endogenous growth model, the new design which comes as a result of technological change and scientific research is neither a conventional economic good nor public good, but they are non-rival and partially excludible inputs. This argument supports the three premises and results in aggregate growth in the form of capital accumulation by using non-rival partially excludible new design, the second premise is supported by partially excludability where technological change comes from intentional incentivized actions of profit maximizing people and third is that technological improvement is a non-rival good. Here the argument of partially excludible nature of new design is due to the fact that it is belongs to a physical object in the form of human capital with an ability to add.

Based on above arguments, Roamer based his model on four inputs including capital (K) which is measured in units of final goods, labor (L) as skills, human capital (H) as years of formal education and training and technology as an index. Here the human capital (H) is used as a rival component and separated from non-rival component technology (A). The solution for endogenous balanced growth model formulated by Roamer is as follows

$$g = \delta HA = \delta H - \frac{\alpha}{(1-\alpha-\beta)(\alpha+\beta)} r \qquad \text{Eq. (Error! No text of specified style in document..1)}$$

this can be simplified as

$$g = \delta HA = \delta H - \Lambda r \qquad \text{Eq. (Error! No text of specified style in document..2)}$$

here ʌ is a constant which depends upon technology parameters α and β. Moreover, for balanced growth equilibrium, the variables capital (K), technology (A), human capital (HA) and output (Y) remains constant.

Both equations (1) and (2) explains the technological aspects of the model particularly in terms of investment in human capital in research to develop new design with the opportunity cost of wage income that can be earned in manufacturing sector to produce final goods. New design as a result of research generates increase revenues only if interest rate is lower. In endogenous growth theory, more emphasis has been given to human capital in research which leads to increasing return

to scale in future and hence aggregate growth rate which is evident from highest human capital devoted to research in developed countries.

In conclusion, the endogenous growth theory postulates that the best policy to speed up growth would be investment in research and accumulation of human capital. Secondly, low level of investment in human capital and research may be the main reason behind low or no growth in closed underdeveloped economies despite larger population. Hence, economic integration with free international trade can bring about accumulation of human capital and new designs from research because of non-rivalry nature.

Conceptual Framework

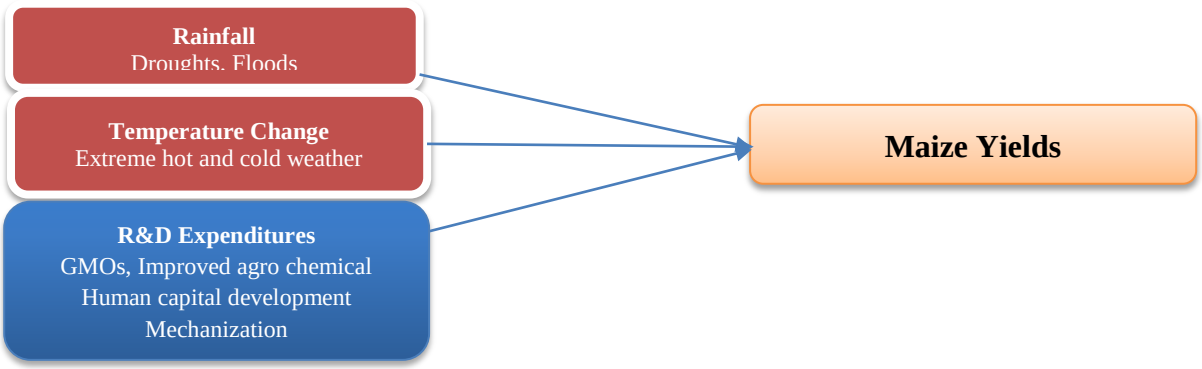

Figure Error! No text of specified style in document..1 Conceptual

Objectives

Objective of this research study is to empirically investigate the relationship between maize yield and climate variables in the neighbouring South Asian economies. The study also incorporates the role of Research & Development Expenditures in mitigating the negative shocks of climate change.

Research Methodology

This section of the paper include the material and methods used to estimate the relationships between study variables.

Sample Data

Quantitative data from the year 1996 to 2018 was obtained from different data sources. The detailed information on study variables such as maize crop yields, climatic variables (temperature and rainfall) and R&D expenditures was obtained from various online sources such as FAOSTAT, World Development Indicators (WDI), Economic Survey of Pakistan, and Trading Economics. The data is organized in Microsoft Excel 2013 and analyzed in the statistical package Eviews version 10.

Econometric Models Specification

Autoregressive Distributive Lag model is used to investigate the short and long run relationship between study variables in each sampled countries. The ARDL models can be applied in case of one cross-section unit. But, in a panel setup, there are several cross-section units, each of which has its own set of effects. In empirical research studies, the PMG also known as Panel ARDL estimator offers several benefits. The PMG estimator is not restricted in this way, and it may be used to both stationary and non-stationary variables. Because of the association between mean-differenced repressors and the error, ARDL regression estimation becomes skewed in this situation (Zare et al. 2014). As a result, it is not necessary to pre-test the stationary property of data before using the PMG estimator.

Econometric model specification is given as follow

$$YIELD_{it} = f\,(R\&D_{it} + AVGRF_{it} + AVGTEMP_{it} + AVGTEMP^2_{it} + LAND_{it}) \quad \text{Eq. (Error! No text of specified style in document..3)}$$

$i = 1,2,3,4,5$

Here,

$YIELD_{it}$ = Yields of maize crop of Pakistan, India and China

$R\&D_{it}$ = Research & Development Expenditures (percent of GDP)

$AVGRF_{it}$ = Annual Average Rainfall in mm for Pakistan, India and China.

$AVGTEMP_{it}$ = Annual Average Temperature in Celsius for Pakistan, India and China.
$LAND_{it}$ = Land allocated maize crop

Results and Discussion

This section explain the findings of the study in three steps, in first step the descriptive statistics of study variables are explained. In section 2 and 3 respectively we explained the results of ARDL model for individual countries and PMG for all three sampled countries collectively.

The descriptive statistics of maize data justify the high productive capacity of china with average yield of 64989 hg/ha, while Pakistan and India remain on second and third position with 33031 hg/ha and 32715 hg/ha respectively.

Table 1. Descriptive Statistics of Maize Yield (hg/ha)

Wheat Yield	Minimum	Maximum	Mean	Std. Deviation
Chin	60606	70280	64989.13	2845.36
India	26163	38782	32715.17	3663.39
Pakistan	27542	38526	33031.91	3709.18

Long Run Estimates of PMG

The long run and short run estimates of Pooled Mean Group (PMG) of maize yield are given in table 2 Analysis show that maize productivity have positive response to research and development expenditure in sampled countries. Maize crop registered positive response of 12, 51 and 1 percent respectively to R&D expenditure, temperature and rainfall in the long run. Similarly, increase in area under cultivation have decreasing role in production of maize crop. In the short run the role of R&D, temperature and rainfall adversely affected maize productivity in the region of three sampled countries, but the area under maize crop have positively affected crop yield. Analysis in table 2 also reveals that further increase in temperature after threshold point decreases crop yield by 25% and 1% in the long and short run situations respectively.

Table 2. Long and short-run Estimates of Pooled Mean Group (PMG) Model

Variable	Long run	Short run
R&D	0.1184* (0.0338)	-0.0530 (0.0426)
TEMP	0.5242* (0.1446)	-0.0023 (0.0627)
TEMP^2	-0.2513* (0.0746)	0.0151 (0.0400)
Area Under Crop	-0.3317 (0.2109)	0.4478* (0.1404)
Rainfall	0.0121* (0.0037)	-0.0015 (0.0012)

*Note: *, ** and *** represent significant at 1 %, 5 % and 10 % respectively.*
The values in the parentheses are standard errors values.

Country wise Comparison

Maize productivity vary in different countries and similar is the response to different intervention and climatic factors. The yield is highly dependent on previous history which shows the level on development and other fertility factors have achieved to the optimum level, in China and India lag year yield have highly significant coefficients of 0.7358 and 0.6030 respectively as compared Pakistan's -0.7074 which reflects on the cobweb phenomenon operating in Pakistan. R&D produces significantly positive effects in all sampled countries as indicated by highly significant coefficients. Moderate increase in temperature is insignificantly associated with maize yield by 11, 7 and 22 percent in China, Pakistan and India respectively. However, more rise in temperature than the threshold level has negative effects. Higher increase in temperature have insignificant and negative impact on maize productivity and having decreasing effect of 14 percent as compared to 9 and 21 percent of China and India respectively.

The short run results are insignificant except lag yield and area under maize crop. Previous year crop yield negatively affect current year production and whereas the area under crop positively affect crop yield in the short run. Summary of the findings are given in table 3.

Table 3. Long and short-run Estimates of ARDL Model

Variable	China	India	Pakistan

Long Run Equation			
Lagged Yield (-1)	0.7358* (0.1421)	0.6030* (0.1369)	-0.7074** (0.2655)
R&D	0.1875** (0.0493)	0.1162 (0.0692)	1.3638* (0.2664)
Area Under Crop	0.4200** (0.1058)	0.0566 (0.1902)	-0.0735* (0.0148)
TEMP	0.1145 (0.0754)	0.0751** (0.0305)	0.2281 (0.1644)
TEMP^2	-0.1403 (0.0758)	-0.0919 (0.0996)	-0.2104 (0.1566)
Rainfall	-0.0066* (0.0012)	0.0048* (0.0021)	0.0039** (0.0012)
Short Run Equation			
Lagged Yield (-1)	-0.2777 (0.1847)	0.5818** (0.2688)	-0.7756* (0.2305)
R&D	0.0052 (0.0516)	0.0004 (0.0749)	0.0683 (0.1529)
Area Under Crop	0.2275 (0.1691)	-0.2977*** (0.1563)	0.2529* (0.0748)
TEMP	0.2009 (0.1347)	0.0444 (0.0344)	-0.0141 (0.0717)
TEMP^2	-0.0924 (0.0685)	0.0224 (0.0414)	-0.0405 (0.0908)
Rainfall	0.3187 (0.6933)	0.0012 (0.0018)	0.0003 (0.0011)

*Note: *, ** and *** represent significant at 1 %, 5 % and 10 % respectively.*
The values in the parentheses are standard errors values.

Discussion

Analysis show that maize yield have positive response to Research & Development (R&D) expenditure in sampled countries. Our research findings are in line with most of the similar research findings in other parts of the world. With the passage of time and increasing population and demand for food, many high yielding varieties are introduced which have significantly contributed to increasing productivity. These varieties are able to bear temperature and other climatic shocks and also cope abnormal weather conditions. The scientist of Pakistan Agricultural Research Council (PARC) are busy in research and developing new verities. Pakistan has been experiencing maize low yield in comparison with other two countries due to various issues like inappropriate use of inputs, water shortages and mismanagement of the part of policy makers looking at maize import and export. The climatic condition has not affected wheat production in Pakistan as it did in tropical regions (Janjua, et. al., 2014). However, with high yielding varietal development, these issues can be utilized for macroeconomic benefits in the form of foreign reserves and trade and commerce development. World food organization is also contributing to maize production development for increasing food supplies to the people affected by conflicts in the ongoing war on terror. Research on different maize varieties have helped in obtaining grain with desired nutrient characteristics. Similarly, farmers are using hybrid maize varieties due to increase in commercial use. Unlike, past maize is no more used for staple purposes of poor people and it is used in poultry feed as well as edible oil industry. Conventional maize varieties were unable to cope more rains and storms and their delicate plants always resulted in breakage and low yield. However, new varieties developed can bear those shocks and have been resulting in higher yields. The multinationals like Syngenta, Monsanto has contributed much to hybrid maize adoption. Currently locally produced hybrid varieties like Azam, Babar and more have penetrated which have higher yields than conventional varieties. The GM technology has helped in realizing maize with desired characteristics, it not only helps in current productivity rise but also helps in solving potential issues in future (Chavas, et. al., 2014). Likewise. Bt maize varieties

have helped in increasing yields in less-than-ideal conditions for maize. In these condition Bt maize perform far better than conventional maize varieties and enabled African farmers to use less seed and get more grains unlike conventional maize (Gouse, et. al., 2006). Seed rate is inversely related to yield and modern varieties have decreased seed rates which had decreased number of plants per acre and more grains (Fatima and Khan, 2015).

Similarly, looking at the importance of maize and its increasing requirement in feed industry and expected rise in demand, two maize research institutes were opened, in Yousaf-Wala and Pirsabak. Their mandate was to develop open-pollinated verities (OPV) of maize crop in collaboration with International Wheat and Maize Improvement Center (CIMMYT) Pakistan. Pakistan Agricultural Research Council (PARC) also coordinates research activities in different parts of the country which results in steady rise in maize yield. Focus has been given on development of hybrid verities for arid zones and highland areas. The research output is the development of quality protein maize verities which are high yield, taking fewer time in maturity, drought and heat tolerance, disease and insect resistance. Different maize varieties with good potentials like SOAN-3, Agaiti-2002, Kissan, Pahhari, Azam, Agaiti-85 for rain-fed areas and Kashmirgold, Golden, Sahiwal-2002, Sarhad-white, Sarhad-yellow, babar (Hybrid), Ghauri (Hybrid) FH-421, Fh-810 are recommended varieties with high yield potential for irrigated areas (Tariq and Iqbal, 2010).

Maize yield registered highly significant positive response 1.3 units to a unit change in R&D expenditure. In a similar study in Africa for same crops by (Alene, 2009) reported that the estimated productivity elasticity of R&D investments is 4%. Temperature rises have positive impact on maize productivity as maize is grown in summer and used to heat. These are short duration crops where watering can overcome the stress of overheat for some times. Research has focused on developing varieties for adapting maize to heat stress as it is summer crop. The findings of this study regarding effects of heat and temperature rise are in contrast with other studies who have reported negative effect of heat and temperature on maize yield (Cairns et al. 2012; Mayer et al. 2014; Rezaei et al., 2015). However, the effect is negative when temperature rises and exceeds 30 C while here in Pakistan maize is mostly grown in cold regions. (here is the negative effect of temperature is because of the region high level of temperature and further increase in temperature will havoc crop yield in the region. Short episodes of high temperature near flowering stage can have significantly negative effects of grain yield in maize (Zare et al. 2014). Similarly, increase in area under cultivation have increasing role in production of maize crop in China and India but have negative role in Pakistan. The inverse relation of maize productivity and farm size are evident from many other studies (Byirnigiro and Reardon, 1996). Rainfall have positive impact on maize crop productivity in India and Pakistan. The reason is that rainfall is associated with drop of some degree in surface temperature during maize crop season which have positive effect on yield level as reported by (Alene, 2009).

Research and Development expenditures and other climatic factors have both short term and long-term effects on agriculture productivity. Though Research and development have positive impact on crops productivity in long run, however, short run effects of R&D expenditures are positive in sampled countries but statistically insignificant. Most the previous research have also shown insignificant role of R&D in the short run as these expenditures takes enough large time to introduce new technologies and innovation in agriculture. The results are in line with previous studies of (Alene, 2009 and Salim & Islam, 2010).

Conclusion & Recommendations

Increasing agriculture productivity has gained much importance generally and in countries with higher populations in particular. Like other countries, Pakistan, India and China much dependence is made on agriculture sector for earning income and generating employment. With the passage of time, increasing population and demand for agrobased inputs in industrial sector, the importance of increasing agricultural productivity has gained momentum. Like other sectors, agriculture sectors has shown positive response to R&D expenditure. However, it is more effective in long run while the short run effects are mixed. Crop wise the responses vary both in short as well as in long run across different geographies**.** It is concluded that R&D play important role in increasing maize productivity both in short as well as in long term. However, the effect is more dominant in long run and a unit increase in R&D expenditures increase maize yield by 0.18, 0.11 and 1.3 units in China, India and Pakistan respectively. Other climatic factors like rainfall, temperature level have positive effect in the long run for the region of sampled countries in the long and have negative effect in the short run.

Country wise, the effect of temperature increase is positive in all countries and temperature increase is an increasing function of maize yield. The coefficients of rainfall are positive in India and Pakistan but it is negative in China. Lag year maize yield have positive effects on current year maize yields in Pakistan and China whereas, in India the effect was reverse for lag year yield as well as area under crop.

New high yielding varieties to be disseminated to small farmers on subsidized rates so that they can play their role in enhancing agriculture sector. Research should be conducted on social aspects of farmers to enhance their adoptability of innovative technologies developed for high yielding agriculture. Also decreasing cost of production be considered as it hinders farmers adoption of new and innovative technologies. There should be no waste of time in implementing R&D agendas as any delay in policy implementation may cause crossing threshold level of various climatic factors to produce adverse effects.

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