Economy's response to Rainfall and Economic factors

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Abstract

Agriculture, known to be particularly sensitive to rainfall, helps determine GDP by its own performance and through its linkages with the industrial sector. Using Factor analysis to spatially disaggregate meteorological rainfall data based on commonality and employing an econometric simultaneous model the study finds determination of sectoral GDP performances in the economy to be a complex process. Although irrigation is making agriculture resilient to weather, irrigation itself depends on rainfall elsewhere and in past periods. Rainfall in different periods of the year and in the past and in disparate parts of the country together shape performance of the primary sector, especially its direction but the impact of rainfall on the secondary sector is relatively weak. Prices, policy variables, interest rates and exchange rates matter for both sectors but reactions may come with a delay especially in the secondary activities. Subsidized targeted credit for agriculture is found to help both sectors. For current agricultural performance, the criticality of good water management is implied by the highly influential role, not always favourable too, of rainfall in the previous year.

Key words: Spatial rainfall, Factor analysis, policy effect, price effect, Water management, sectoral GDP

1. Introduction

Even as agriculture's share in India's national income diminishes, it helps to determine GDP not only by its own performance but also through its linkages with other economic sectors. Indian institutions monitor, regulate and manage the economy guided by policies even while price signals in markets remain important in deciding the directions to be taken by the economy. Water is a valuable natural resource that is used by all sectors though in varied extents. The largest user is agriculture that consumes 78% of India's water compared to 8% taken by manufacturing and other industries while domestic uses including drinking water claim only 6% (CWC, 2014).

Indian agriculture has always been particularly sensitive to rainfall which makes also other sectors concerned about weather not only because water is competitively required by most activities but also because, employing about half of the nation's workforce, the agricultural sector presents them with market. Expectedly, prudent water management would insulate all sectors from crippling deficits and devastating excesses of water that endanger economic activities. With the expansion of irrigation there is a sense that agriculture has become more resilient to local weather calamities but irrigation itself depends on rainfall elsewhere and in past periods. The economy's dependence on rainfall therefore has large temporal and spatial dimensions that cannot be simplified by averages.

Conventional assessments treat annual or monsoon rainfall to be normal if the all India average is within set bounds of a long-term average (Indian Express, 2019). The significance of seasonal distribution of rainfall and the regional variations of monsoon in a vast country is gaining increasing recognition especially as the country senses the threats of climate change (Kulkarni A. et al. 2020, Singh and Mal, 2014). Even in a year of conventionally normal monsoon, shortfalls in relevant growing months and in critical producing zones with or without sync with the all India pattern, can hurt national farm incomes and disrupt industrial activities undermining the significance of the national average. Similarly, untimely or unexpected downpours and floods in some region can be as destructive. Monsoonal aberrations therefore regularly raise apprehensions about the outlook of the integrated Indian economy. To understand the nature and strength of the associations expected among sectoral performances with rainfall, correcting for policy and prices, this study employs statistical and econometric methods incorporating temporal and spatial perspectives to identify the weather indicators that influence performances of two major sectors of the Indian economy.

2. Objective, Theory and Method

The objective of the paper is to measure the sensitivity of sectoral GDP (SGDP) of the two sectors, narrowly identifiable as agriculture (AFFMQ) and industry (MCEGW) at the all India level to rainfall and to identify the spatio-temporal profiles of the rainfall measures that prove influential for each sector by estimating an econometric model using time-series annual data for the period 1985-86 to 2019-20. The two sectors comprise of activities as set by the official data protocol that divides Indian economy into different sectors (CSO, 2012). Each of the two sectors are in reality broader, perceivable as primary and secondary sectors where AFFMQ denote primary activities in agriculture, forestry, fishing, mining and quarrying and MCEGW denotes secondary activities in manufacturing, construction, electricity, gas and water supply. Agriculture and manufacturing constitute 85% and 64% respectively of the two SGDPs.

The explanatory variables in the model relate to weather, markets and to policy administration. Spatial and dynamic impacts are taken into account based on both intuitive understanding and empirical revelations made by data. Autoregressive variables for the concerned sectors are considered for allowing dynamic and inter-sectoral effects in the model. Given that the activities, resulting in output flows, require prolonged periods of planning, formation of subjective anticipations of the future that are influenced by past experiences and more particularly with the water effect of rainfall percolating over time through soils, rivers and reservoirs, lags in specification, not with determinacy, are intuitively expected for describing the SGDP determination. The data is permitted to determine the lags in the specifications of the equations through the diagnostics of the model, i.e., statistical significance. The theoretical proposal underpinning the model is laid down below.

2.1. Theoretical conjectures on Explanatory factors

Rainfall (RF): In popular parlance, monsoon refers to the months June to September (IMD, Website) when major crops including rice are grown in the country, marking the kharif cycle which contributes half of India's annual foodgrain output. Not just the average but also the temporal rainfall distribution within the season is important for growth of crops which vary in their biological responses to water at various time points in their growth cycle. Apart from the monsoonal crops, the rabi season, important for wheat, mustard, vegetables and pulses, is also an important contributor to production from agriculture. Rainfall in monsoon and post-monsoon months matters for rabi season when the monsoon is no longer active and also for determining the soil moisture and irrigation potentials of future agriculture. India is a large and diverse country where crop calendars differ in line with climatic and geographic variations. Some states have a third crops (like boro rice in West Bengal, zayad maize in Bihar). With the monsoon tending to waiver in its arrival, departure and in its intensity and with the advent of new seeds and technology, cropping seasons have hardly been sharply defined in recent times.

Irrigation can substitute current rainfall where and when it is scarce. Based on construction works on dams, spillway tanks and other structures, irrigation itself makes use of rainfall that is uneven over time and space. Its efficacy depends a great deal on the quality of water management and redistribution by administrators. Nearly half of the cropped area in India is irrigated so that incidences of past and current rainfall across catchments and slopes as well as water management standards followed, especially drainage practices, can be expected to be decisive when excess water can even be harmful for many crops. Means for harnessing ground water, surface water and conjunctive irrigation systems (Dhawan, 1993, Vaidyanathan, 1999) have depended on technology and practices. Newer water saving and micro-irrigation systems are becoming popular. Water is also important for horticulture, dairying, mining and forestry within AFFMQ, although natural rainfall is more important for these activities. Sectors like construction and electricity generation also suffer from water deficiency while excesses of rainfall, especially intense showers, can seriously disrupt any economic operation.

To capture the temporal dimension of rainfall within a year, a month in the rainy season is treated as the temporal unit of rainfall. Historically, June marks the start of monsoon[1] and the period of traditional kharif sowing. The season covering July, August and September is the peak of monsoon for crop growth while October and November mark the end or return of the monsoon or the post-monsoon season when kharif harvest begins and water moistens the soil before rabi sowing. December and January are the winter months with the soils carrying the rabi crops when some kharif harvesting still continue and finally, February, March, April and May are the driest months making up the spring and the summer seasons together.

[1] The demarcation of the monsoon season may change associated or not with climate change. In 2021 the monsoon may have arrived in Kerala in May end and in the month of May India received copious rainfall. In 2020, monsoon end came with delay.

Rainfall data is reported by IMD (IMD, Website) from 36 meteorological sub-divisions (MET-regions) of the country some of which denote sub-state or state coverage but some others overlap across neighbouring states. While employing IMD data, the names and their abbreviations of the MET-regions used are as provided in Appendix Table 1. The period of rainfall considered is not confined to the study year but its impact is allowed to spill over to future years. Each variable on the right including rainfall is allowed to appear not only at the currents level but also with lags of up to 4 years even at the cost of degrees of freedom. Rainfall in India varies across the sub-continent but slopes, river basins and canal networks connect the country hydrologically so that the effect of rainfall spreads spatially. With monthly rainfall of the METs specified for the current study year and four preceding years, the rainfall observations would make up (36 X 12 X 4) 1728 variables in any equation. Weather across regions are not independent of one another as rainfall often results from wind movements caused by depressions and long monsoon troughs. Facing this collinearity problem and the unwieldiness of the number of rainfall variables, data reduction is conducted.

Seven months of the year June to December officially covering the monsoon (beginning June to September end) and the post-monsoon (October to December) months (IMD, Website) and accounting for 88% of annual rainfall (Appendix Table 1) are only taken into account for analysis. The five largely dry months January to May are excluded when limited parts of the country do receive some rainfall from western or local disturbances but the proportion is small (12% of annual rainfall). To further reduce data, Factor Analysis using SPSS software is employed ensuring orthogonality. Each of the 7 studied months is represented by Factors that represent rainfall with spatial dimensions and significance, assumed to be reflecting an underlying commonality within each factor and also expressing varying loadings of a Factor on the disaggregated rainfall of METs in the month.

At the first stage, the METs that express low communality of rainfall, of less than 50% in any month, are excluded (Appendix Table 4) for standing out in the country. The statistic Kaiser-Meyer-Olkin (KMO) guides us in the exclusion as suggested in literature (Chan and Idris, 2017, Costello and Osborne, 2005). Thus, JK, EH, LD, SI for June, UT, EH, AN for July, AN, UT, EH for August, CA, OR, TN, EH, CK for September, EH, AR, AN for October, JK, AN for November and LD for December respectively go out of the analysis for their communality values of range 24% to 48%. This helps to ensure KMO value for any month to be at reasonable levels, more than 60% in 6 cases and not less than 50% in all cases for the Factor analysis to be meaningful. Important for effective analysis of data, the limitation imposed by the process is not trivial given that valuable rainfall information is lost by the elimination of some mountain METs located in upstream river basins like JK, EH, AR and UT, certain heavy rainfall receiving plain areas in METs like CA, OR, and CK and rain deficient METs like SK and TN.

The first factor F1, covering a set of METs with high loadings, has the power to explain the largest proportion of variation (Eigen values) and therefore is the most representative of the national rainfall that differs over the year from scarcity to abundance. It is followed by other factors F2, F3, F4, F5, F6 and so on respectively in that order (Appendix Table 2a & b) but for this study the first six Factors are only taken into account because the composition of these Factors represent the widest possible regional spread which is a revealing element. For the purpose of the regression analysis the Factors identified by principal components analysis are rotated for orthogonality and independence using Varimax and Kaiser Normalization. The principal 'Eigen value', not less than 1.5 (Samuels, 2016) and the 'rotated sum of square' reported of the first six Factors along with their principal components show how the Factors explain rainfall in the month. The Factor analysis reduces data covering 36 met-regions to 6 Factors embedded with their underlying spatial dimensions for each of the 7 months. The detailed results are given in Appendix Table 2a & b. In an alternative specification, information lost due to statistical constraint is retrieved by separately considering the METs excluded on grounds of low commonalty. This allows the added residuary METs emerging independent of other METs, to reveal their own importance in describing India's climate.

Markets: Like weather, market mechanism is largely beyond control of farmers and even policy makers have only partial control. The agricultural market communicates with economic agents and other markets through price as a signal. Prices act as signals to farmers and agri-businesses to interact and invest in the sector. Wholesale price indices of different items separately and as commodity groups and as an all commodity average are reported officially. Prices received by the farm sector are indicated by food article price (WPI- food article) and alternately by a composite primary commodity price (WPI-primary) where WPI stands for wholesale price index. Given the general price level (WPI- all) or price levels of manufactured goods (WPI-mfg), higher prices of farm goods can be income enhancing to farmers through implicit terms of trade as also beneficial for industry through inter-sectoral transactions. On the other hand, food being part of wage cost of labour, it is also possible that higher food prices have a depressive effect on the non-agricultural sectors or even the farm sector.

The government interferes with (some say distort) market generated prices to a limited extent. Energy and fuel are two major sources of cost facing agriculture as well as other sectors. Most input costs are fundamentally influenced by fuel price incurred for transportation along value chains and by energy prices that determines the operational costs of production. We proxy fuel by oil (high speed diesel or HSD) and energy by electricity. In agriculture, transportation cost adds to total cost of cultivation and marketing. Reduced energy price economizes on the costs of irrigation, mechanization, post-harvest operations and processing. Price of electricity (WPI-energy) and price of HSD (WPI- fuel) are available from official records (MoCI, Website). Prices of fuel and energy are largely administered in India and moderately insulated from global influences. Although these two prices add to cost and reduce value addition, in industry (MCEGW), many firms are engaged in the production and distribution of fuel and energy (electricity oil and gas sector) and could actually gain from higher oil or electricity prices making the prices and the performance of the industrial sector mutually correlated.

Certain commodity prices are pivotal. Fertilizer and pesticide are inputs in agriculture though the former is intricately related with fuel and latter with chemical sectors in industry. Similarly, industry especially construction depends on metals and cement as inputs. Agriculture too can be related to metals for mechanization and cements for constructed assets as support structure. Finally, food product considered as a separate product group comprising processed food articles, is related to both agriculture and manufacturing and in fact, serves to physically link farming with manufacturing. Although it is an output of industry included in MCEGW and its price an incentive to the sector, the same incentive will enhance demand for agricultural products and thereby promote the primary sector. On the other hand, being ready-made items of consumption (such as dairy products, packed and dehusked cereals and pulses, extracted edible oils and snacks), higher price of food product can add to wage cost in both sectors and the net effect is a result of the strength of the conflicting pressures.

Thus, apart from WPI-all, WPI-primary, WPI-mfg, WPI-fuel and WPI-energy and WPI-food articles, commodity prices WPI-metal, WPI-cement, WPI-pesticide, WPI-fertilizer and WPI-food products are among other explanatory variables. In any macroeconomic framework prices are determined in sync with outcome indicators, so that endogeneity in an econometric model may create bias making instrumental variables merit application. In this analysis all prices are taken as indices at a common base of 2011-12 in nominal terms. All price variables are also regressed on their past 4 lagged values to obtain respective instruments. Both observed prices and their instrumental variables are tried as options to correct for possible endogeneity.

Policy interventions: Farmers' welfare and poverty alleviation of farm labourers are politically sensitive issues. Procurement of food grains at pre-announced minimum support prices (MSP), meant for mitigating price risk inherent in agricultural markets, is open-ended and voluntarily so that farmers are free to dispose of any amount in the free market at the prevailing price but the volume of procurement depends also on the effort exerted by the assigned public administrative machinery. Seemingly, lowering of procurement volumes will leave larger share of produce at the mercy of the market, not only hurting farm incomes but also acting as a disincentive for production in the following years but in reality, the implication is ambiguous. Government's failure to fully meet its commitment can extremely be damaging. Albeit it's stabilizing effect, by distorting market prices, procurement could deprive farmers from the unknown potentials of domestic and global markets, trapping farm incomes at low levels. Although distribution of low priced grains, by keeping food prices and wages low, encourages production in other sectors, large volumes of procurement weighing on the public budget, deter financial flows for investments and over time, with unmatched public distribution, they may raise market prices by holding grains away from the market.

The government supports agriculture in other ways too. The farmers need finance to procure inputs like fertilizer, seed, pesticide in time and for medium-term investment on irrigation and other mechanized farm services. A quota for priority credit towards agriculture is given to the financial system which operates within an integrated system of rural credit working through various banks that are apex, scheduled, nationalized and private, a cooperative network and now also through a system of credit card to work at the field level with farmers (Kisan Credit card). The system allows farmers to borrow from the financial institutes at market rates of interest and also offers the ease of availing insured short-term credit (Ag-credit) as and when desired at affordably low interest rates that are publicly subsidized.

The RBI (India's central Bank) and the government have a hold on finances available to all economic operators by influencing the rate of interest through planned transactions in dated securities. Average of interest rates on bonds of maturity over 1 year issued by central and state governments are indicative of borrowing cost presuming also that the rate changes on these bonds would be passed on to borrowers by concerned banks and societies. Expressed as Bond rate (Bond-rate) for central and state government issues, they are regulated but also market based, as the bonds are allowed to be transacted. Over a larger horizon of time, agriculture can also be a beneficiary of monetary operations that allow finance to flow towards farm mechanization, land development, water management and the input industries. It can be strongly argued that, coming through capital formation and resultant output growth, low long-term interest rates might help growth in both farming and industries but with a time lag.

Finally, produced goods may have markets overseas but on the contrary, often the inputs necessary are imported. The exchange rate (Exchange-rate) specified as the price of USD in rupee (inverse of the value of a rupee) has a profound impact on SGDP. Higher exchange rate, signifying devalued rupee, can expand exports by making the exportable goods cheaper outside the country but if the USD costs less to the domestic businesses, imports become cheaper, reducing the costs of sectors or sub-sectors that draw on imported technology or inputs. The value of rupee is regulated by RBI but is not completely resilient to dictates of world market forces as relaxation of many regulations followed the onset of liberalization.

2.2. Model

The weather variables in the model are the six independent Factors of cross-country MET-regional monthly rainfall in the period of 7 wet months, June to December. Market and policy variables are prices, bond rates, food grain operations and exchange rates. All the variables are used at current levels and with their lags up to 4. The Econometric model estimates SGDP in the two different sectors as dependent variables. Economic variables are taken at first differences of nominal values to minimize problems of non-co-integration so that the left side variable indicates the annual increase of a sector in nominal value

Different alternative specifications of equations are tried. Selected equation for reporting and exposition show coefficients only with t-statistics over one. Theoretically, the two interlinked sectors in an integrated economy may be affected by similar external shocks making the errors covariate which suggests that simultaneous estimation is likely to produce more efficient estimates. After choosing the single regression equation specification based on diagnostics (t-statistics, signs and fit), the equations for the two sectoral SGDP with chosen specifications are estimated simultaneously by seemingly unrelated regression equations (SURE[2]) method. Instruments for price variables are used to take care of endogeneity.

The equation for any sector is

$SGDP_{kt}= f(RF_{m,F,t-j}, P_{i,t-j,}, L_{n,t-j}, SGDP_{k,t-j})$

Where RF is rainfall, subscripts are m= months (June to December), F= Factors (1, 2, ,..6), representing MET regional units, t= year, j= temporal lag (0 to 4), i=indicator code for price variables (P), n is indicator code for policy administered variables (L), and k= indicator code for sector (AFFMQ, MCEGW). The estimated errors are tested for stationarity with a ADF statistics and plotted with the dependent variables (Figure 1).

The equation is linear in first differences with the signs of coefficients showing the direction of effect of variables increases. Over time the contribution to changes in SGDP will depend on the sign and magnitude of both the coefficients and the changes undergone by the explanatory variables. At any point, the estimate of the dependent variable will be determined by the respective coefficients and values of variables. The contribution of any explanatory variable group X is $(\Sigma\beta_i X_{it})/SGDP_t$ where X_i is the variable belonging to group X in year t and β_i is the corresponding coefficient. Over a period when SGDP increases by ΔSGDP (> or < or = 0) contribution of X towards this is calculated as $(\Sigma\beta_i \Delta X_{it})/\Delta SGDP_t$

The variables both Dependent and Explanatory are as explained below.

Dependent variable: Sectoral Gross domestic product (SGDP)
SGDP = sectoral GDP in Rs. crores at current prices and measured in first difference, where the sectors (k) are

1: Agriculture: agriculture, forestry, fishing, mining and quarrying (AFFMQ) alternately mentioned as ‘agriculture’ or ‘primary’,
2. Industry: manufacturing, construction, electricity, gas and water supply (MCEGW) alternately mentioned as ‘industry’,

[2] Seemingly Unrelated regression estimation

2.3. Explanatory variables:

Rainfall (in millimetres) measured by 6 Factors for 7 months (month-F up to 4 lags), Price levels measured by wholesale price index (WPI) with base 2011-12 including WPI-food article (raw food), WPI-fuel (HSD), WPI-pesticide, WPI-fertilizer (chemicals NPK), WPI-cement, WPI-energy WPI-metals (Basic Metals), WPI-food products (processed food), WPI-all (general price level), WPI-primary (agricultural raw products, raw metals, forest products water/marine products etc.), WPI-mfg. Policy variables are administrative given by the Bond-rate (rate of interest in market on non-short term loans or rate of interest on Bond), Ag-credit (credit available to farmers at subsidized interest rate in Rs. Billion), food procurement (food grains in million tonnes purchased at minimum support price by government) and Exch-rate (in Rupees per US Dollar or the inverse of the Exchange Rate)

3. Results

The results are discussed below with respect to three broad concerns, namely the regional and temporal dimensions of rainfall that matter for the two sectors, the role of rainfall in shaping performances relative to other variables comprising of prices, policies and the past trend and finally the quantified contribution of rainfall compared to other factors to the estimated SGDP and the change in SGDP over a period. The simultaneously estimated equations show R-Square values of 0.99 and 0.98 and RMSE and correlation between estimated and actual values of the dependent variables (Table 3). The errors (Appendix Figure 1) show a tendency to be low below 5%.

3.1. Rainfall dimensions

The first six factors together account for at least 60% of the variations in each of the months concerned. Considering the METs with top 5 loadings, while exploring each factor of any month for its underlying the attributes, different geographical coverages in continuity are often evident. The five top METs, with a few exceptions, have fairly high loadings on the Factors, ranging from 0.6 to 0.9. The First factor F1, most representative of the country's rainfall, accounts for 15%-26% of variation in the 7 months. It covers northern and north-western states respectively for June and October rainfall levels but rainfall in southern, western and central MET regions have greater influence in determining national rainfall in other months.

Rainfall in two eastern states Odisha and Chhattisgarh and the whole of Madhya Pradesh appear in F1 for July while southern states, especially Karnataka, stand tall for November but F1 includes the MET Vidarbha in Maharashtra in both the months. In August the principal factor F1 consists of two different regions, one in the east and north-east (SW, BH, AP) and the other in peninsular parts of Karnataka and Andhra Pradesh. In September the representative regions starting in Kerala reach out into interior peninsular India covering parts of Karnataka (NI), Maharashtra (MM and MT), Andhra Pradesh (RY) apart from Kerala,. Rainfall in Punjab, Haryana and Rajasthan is influential for Indian climate in October but for June, Uttar Pradesh and the Himalayan states Uttarakhand and Himachal Pradesh are important besides Bihar, which though a neighbour of EU, is an outlier from the east.

Factor 2 mostly is represented by southern and western regions except that northern-western states (Uttar Pradesh, Punjab, Haryana and Himachal Pradesh) matter for August. While F3 in August and F2 in September reach out to western states comprising Gujarat and Maharashtra (KG, SK, GR, VD) and a part of Rajasthan (ER), METs in the east and northeast, finding some place in the last three Factors in five months, have meagre role in determining national rainfall. In fact GW, the highest rain receiving plain state has a place in F4 in October and November, F5 in June and October, F6 in September and none in July and August.

3.2 Model result for rainfall effects

At the outset it is noted that a good Indian monsoon on the average or F1 turns out to be a curiously weak indicator of how agriculture will perform. Though rainfall in northern India appeared important in shaping the national average in certain months, SGDP of agriculture (AFFMQ) seems to be affected more powerfully by rainfall in the south, east and central India. A second feature of the results for AFFMQ is the importance of rainfall not only in the current year for determining the SGDP but also that of the previous year possibly acting through the water reserves in dams and sub-soils and the irrigation facilities available. Third, the effect of high rainfall is no less adverse than it is favourable though the place and timing matter.

Favourable for the agriculture sector are current July rainfall in the eastern plain regions and current August rainfall of the south-western part of India. July rainfall of southern peninsula stretching from the east to the west and the November rainfall of both west India and west central India in the previous year are also favourable. June rainfall of both current and previous year in the east and north east part of India mostly comprising hilly geography appears adverse for agriculture. Previous year's October rainfall in central India encompassing Bihar and entire states of Uttar Pradesh and Madhya Pradesh also hurts agriculture of the year. While July rainfall is found to be supportive of the sector, June rainfall does not help in the year or the next through irrigation. Rainfall in the southern peninsula in different months is found to be important for successful performance of agriculture. Late rainfall in the west also helps.

Rainfall in the previous year is observed to be relatively more influential on agriculture SGDP than the current monsoon highlighting the importance of irrigation. The most powerful beneficial effect comes from one period lagged November rainfall in western India (F2) covering Rajasthan, Gujarat and western part of Madhya Pradesh followed by lagged November rainfall in south-central India (F1) which include Karnataka (NI, CK and SI) and a part of Maharashtra and Andhra Pradesh (VD and CA respectively). Next in importance is the current year's August rainfall (F4) across the southern peninsula from island AN in the east to CK in the west and from CA in the north to KR in the south. Lagged July rainfall in the peninsula comprising dry regions of RY, NI, TL and MT in Maharashtra also has a positive effect. The effects of June rainfall are adverse as noted from the coefficients of the current and lagged rainfall in sub-Himalayan West Bengal, Assam, the north-eastern states and Arunachal Pradesh, both indicative of floods and poor water management. Rainfall levels in the northern grain belt covering Punjab, Haryana and Uttar Pradesh are hardly found to matter. However, due to methodological limitations, some of the mountain rainfall in the north like in JK and UT could not be considered for all the months in Model-1.

In Model 2 (Appendix Table 3b), where the excluded METs are given space to take into account their monthly rainfall independent of the six Factors, the estimates undergo only minor changes. Effects of variables economic, policy and weather Factors are largely same in sign and also magnitude but strong independent effects of rainfall in three excluded METs become visible, specifically, the favourable impact of June rainfall of in JK in north, of June rainfall in SI in south and also the September rainfall in Odisha in the east which however creates adverse problems in the following year. The results reveal the role of north Indian rainfall and the favourable effects of June rainfall, missed out in Model-1.

The industry sector (MCEGW), not surprisingly, is less impacted by rainfall. Wherever the impact is observed, it tends to be adverse rather than favourable. The current year rainfall seems more important than in the primary sector. Only an increase in July rainfall in south-western India extending from Kerala and LD upwards to Maharashtra (F4) is good for the SGDP of industry. Heavy august rainfall in the same southern parts of India including in the islands of Indian Ocean (F4) is adverse. June rainfall in the east and north east (F5) hurts SGDP of industry as well as agriculture. Despite its favourable effect in the current year, higher level of July rainfall is western and southern region in the previous year can harm SGDP of industry. Supplementations in Model 2 further brings out negative effects on the industrial SGDP of June rainfall in JK but a positive effect of lagged September rain in Odisha, both effects standing contrary to observations in agriculture.

3.3. Economic effects

Undoubtedly economic activities and their outcomes would be closely associated with a host of economic factors, some of which could be determined by policy, some by the market and others could be a result of design or interaction. Although agriculture is found to be deeply impinged by rainfall is different parts of the country at different points of the growing seasons, nature is not the only factor for its performance. Many prices emerge as causative to the SGDP of both sectors.

General Price level given by variables WPI-all with one lag has a negative and significant effect on AFFMQ indicting the adverse consequence of inflation on agriculture. Prices of fuel, energy and pesticide in the growing year are negative influences on AFFMQ mostly indicative of the significance of modern irrigation, mechanization and transport for marketing of goods. To economise on the parameters, the results presented give the coefficient of the average of fuel and electricity prices for AFFMQ. Though pesticide has emerged as an important cost component, the effect of fertilizer price is not observed to be significant for AFFMQ but that does not undermine the place of fertilizer the most important component of the agricultural input basket. The effect could be subsumed in the negative effects of WPI-fuel, much of fertilizer being derived from the same root as fuel (Gulati and Narayanan, 2000).

On the contrary, given all these prices, as expected, raw food article price (WPI-food articles) has emerged with a positive effect on the sectoral economic outcome in AFFMQ but with a lag of 2. The long lag can be a sign of cyclical movements of prices as well as incomplete commercialization of the sector which results in holding of food stocks in farms for home and labourers' wage consumption in kind. The retention for self-consumption in farms remains reasonably high in India, although marketable surplus of various food crops in cereal and pulses categories has been reported to have grown steadily over time (MoSPI, Website). Adding to the cost of production in the form of household subsistence needs and wage for labourers, higher food prices of raw food articles in the market act as an incentive for producing more on the field rather than purchasing from the market. Price of food products (WPI-food product) also emerge significant but at lag zero. Processed food is produced in the manufacturing sector using farm products as inputs although as a yet small proportion of agricultural output is processed (Ghosh, 2014). The Indian food processing industry accounts for 32% of the country's total food market, one of the largest industries in India and is ranked fifth in terms of production, consumption, export and expected growth (IBEF, 2021). Price of food products is a commercial incentive for farmers creating quick demand for raw material raising farm good prices and thereby the nominal SGDP. Metal is an output of the mining sector included in AFFMQ but metal also acts as an input, being an ingredient of many farm implements and machines such as tube-wells, ploughs, pulleys, tractors and harvesters. The negative significant sign of WPI-metal underscores the role of metal as an input in agriculture.

The industrial sector also shows economic repercussions, though with more lagged effects than agriculture, given its relatively more complex character. Prices of food articles (WPI-food) at 3 lags, cement at one lag (WPI-cement), metal (WPI-metal) at 2 lags and electricity (WPI-energy) and fuel (WPI-fuel) in current year all appear to be determinants for MCEGW indicating their role in shaping wage cost and material cost. In the case of electricity the positive and strong coefficient of WPI-energy at current value may be explained by electricity's dual role as input and output in the sector. Price coefficients of electricity and fuel are both a net effect of both demand and supply forces. Fuel price effect on MCEGW could also emerge from its character as a major importable in the form of crude rather than as a domestic output. Price of food product (WPI-food products) at lag 2 has a favourable effect on MCEGQ which reflects as FP as an output of both agriculture and industry.

3.4. Policy and autoregressive effects

Bond-rate has a negative coefficient in the equation for AFFMQ suggesting the role of market borrowing even for agriculture and other primary activities (interest in informal loans can also be affected by the benchmark bank rate) but the effective bond rate is lagged by four years which might convey the use of market loans for longer term investments. Although, money markets do determine SGDP of the Agriculture sector, government's support through supply of subsidized credit (Ag-credit) given at administered interest rate at 2 year lag and cumulative public procurement of grains from farmers (Procurement-food) in the previous two years help strongly to improve the SGDP of agriculture. Current exchange rate (Exchange-rate) represented by the rupee price of dollar has a positive effect on Agriculture showing that the sector produces exportable commodities which gain from lower price of the rupee. SGDP of the agriculture sector is highly sensitive to the past SGDP.

In the case of industry, cost of credit specified as Bond-rate comes as a significantly strong negative effect at a lag of four as in agriculture. Remarkably, the SGDP of industry is also sensitive to Ag-credit with a lag suggesting that farm credit leads to overall to greater liquidity and purchasing power in the large rural sector that helps industry. Unlike in agriculture, the effect of dollar value, is negative with a long lag showing the importance of imports (of inputs, fuel, investment and technology) for the industrial sector. The SGDP of sector MCEGW has no autoregressive dimension to itself but responds positively to SGDP of AFFMQ with a lag, highlighting the sustained importance of agriculture in Indian economy.

3.5. Comparative contributions

Impact of rainfall on the two sectors seems independent of one another though rainfall in the eastern METs seems to hurt both in June when rice is sown in nurseries. Heavy August rains in the south benefit agriculture but deter industrial activities. Both sectors are sensitive to interest rate, that adds to their cost and to exchange rate where the effect of seems to be contrary. SGDP in agriculture is also favoured by public procurement and subsidized farm credit but the latter also helps increasing the industrial SGDP.

Between 2010 and 2019, both normal years of monsoon, the dependent variable (SGDP in first difference) rose for industry by 50% while that for agriculture came down by -6%. Price change was a powerful trigger (231%) and rainfall change, not surprisingly, a mild one (3%) for the adverse SGDP changes in agriculture (Appendix Table 5) and both variables must have had negative roles on the downward SGDP movement, mitigated by the trend which is tied to past practices and favorable revisions in administrative policy. Changes in price movements and administrative policy amendments contributed strongly to the rise of industry in the whole period while rainfall and more importantly, the trend tended to reverse the direction.

Contrary directions are evident if intermediate drought year 2015 is considered. In the first period 2010-2015 (P-1), the dependent variable in agriculture plunged sharply by -58% but industry performed better. In the second period 2015-2019 (P-2), while agriculture recovered, industry showed little improvement with the dependent variable falling by -32%. In P-1, marked by a monsoon departure, rainfall had a 20% contribution to the adversity of drought in agriculture when administrative policy too had not come to mitigate the loss but prices helped with a -7% contribution but in the industry, both prices and policy contributed positively to the prosperity along with rainfall. In contrast, over P-2, another period of dissimilar monsoon, policy and rainfall both helped the recovery despite a strong negative role (-32%) of price changes. Industry was helped by price and policy changes over P-2 which saw a slump but rainfall's contribution (69%) and a stronger contribution of past trend (81%) dragged industry to its destiny. The trend effect has been stabilizing in agriculture mitigating shrinkages and moderating growth but for industry it supported growth in P-1 and the slump in P-2 and counteracted on the declining tendency in the overall period (lack of confidence possibly).

In the three individual years, rainfall contributed to just over 20% of the dependent variable determination in agriculture but for industry overall the impact was negative. The large positive effects of the constant in all three years seem to assure a minimum performance of primary production in given conditions without manipulated or uncertain influences of prices, policy and weather whereas industry appears subjugated to market and policy. Price has not helped realized SGDP of agriculture in this phase of reform but administrative policy helped as did rainfall. In industry, price effect has been unfavourable though the adverse effect is diminishing over time while administrative policy has a meagre effect. The effect of past performance of agriculture sector matters especially for industry where the above 100% contributions of the past trend suggest how momentum from past is important for creating confidence in market.

4. Conclusion

The study brings out the complexity of the macro-economic sectors of India. Regional rainfall, even if not representative of the national average, is important for SGDP of agriculture. Interestingly, carried over effects of rainfall in the previous year by storage and soil percolation are more influential for the primary sector. Rainfall in the peak monsoon season incident on southern coastal and peninsular India is helpful but the results also underline the criticality of water management for better utilization. The monsoon rain in north-west seems to fail in this regard while eastern rainfall is found to be largely adverse, except that rains in JK and in Odisha[3] are supportive. Rainfall effect is limited on the industrial sector.

Economic and policy influences seem to be highly important for the sectoral performance variations as are the water management interventions. Farm credit helps SGDP in both sectors and cumulated food procurement over the last two years helps agriculture. Fuel and Electricity prices do impose cost but their rise can presumably help industrial sectors in which they appear on the output side. The impact of exchange rate movements suggests potentials for exports from agriculture and the importance of imports for industry. Industry is highly sensitive to monetary policy instruments but interest rate in the formal market has an impact also on agriculture. Also both sector additionally benefits from subsidized farm credit.

Food price, agricultural policy and agricultural performance are important determinants of not only agriculture but also industrial performance. Shortcomings in water management is evident especially in the north and the east. Benefits of rainfall are strong in the south which historically has river basin linkages and water sharing protocols. Agriculture has innate strengths as against industry but changes in prices and policy did not always support the sectoral outcomes over time. Rainfall has a contribution of about 22% to agricultural GSDP and its variations have accounted for the outcome dynamics and for both sectors and especially for industry the importance of lags suggest the usefulness of programmed planning and farsight. .

[3] Thein dam is fed by rainfall in JK which holds the reservoir serving a number of grain growing north-western states and Odisha has important dams like Hirakud, Mandiraa and Rengali.

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Appendix

Table 1: Abbreviations (Abb) of meteorological regions and average all India rainfall (mm) of sample (1985-2019)

Abb	Meteorological regions	Monsoon Rainfall (June-Sep)	Post-Monsoon (Oct-Dec)	Annual Rainfall (June-May)
AN	A & N Islands	1537	656	2761
AR	Arunachal Pradesh	2307	212	3364
AM	Assam & Meghalaya	1471	154	2242
EH	Nagaland,Manipur,Mizoram,Tripura	1186	199	1917
SW	Sub-Himalayan W. Bengal & Sikkim	2079	170	2752
GW	Gangetic West Bengal	1225	174	1642
OR	Orissa	1153	178	1504
JH	Jharkhand	1036	101	1268
BH	Bihar	981	67	1171
EU	East Uttar Pradesh	814	46	928
WU	West Uttar Pradesh	683	32	787
UT	Uttarakhand	1280	63	1636
HD	Haryana Chandigarh And Delhi	505	26	626
PJ	Punjab	528	28	673
HP	Himachal Pradesh	826	78	1302
JK	Jammu & Kashmir	515	121	1180
WR	West Rajasthan	282	11	323
ER	East Rajasthan	602	20	653
WM	West Madhya Pradesh	856	42	930
EM	East Madhya Pradesh	1015	49	1128
GR	Gujarat Region, D & N Haveli	828	28	865
SK	Saurashtra And Kutch	522	22	551
KG	Konkan & Goa	2756	139	2937
MM	Madhya Maharashtra	662	113	814
MT	Marathwada	677	97	817
VD	Vidarbha	919	80	1060
CH	Chhattisgarh	1109	76	1265
CA	Coastal Andhra Pradesh	586	332	1033
TL	Telangana	735	121	937
RY	Rayalseema	439	243	777
TN	Tamilnadu& Pondicherry	304	512	974
CK	Coastal Karnataka	3099	280	3566
NI	North Interior Karnataka	529	135	758
SI	South Interior Karnataka	566	212	941
KL	Kerala	1773	517	2700
LD	Lakshadweep	974	323	1529
All India (calculated simple Average)		**1038**	**157**	**1398**
All India (IMD – Normal)		**881**	**124**	**1177**

Source: using monthly MET wise rainfall data from India

Table 2a: Rotated Matrix from Factor Analysis of rainfall in 36 Met-regions in India- Top 6 factors and top 5 components (using Principal Component Analysis)						
Components	RFJN (June) Initial Eigen value (cumulative) = 63.11, Rotated sum of squares (cumulative) =68.61, KMO = 0.63					
Factor (F)	**F1 [19.9]**	**F2 [12.5]**	**F3 [10.9]**	**F4 [10.4]**	**F5 [7.5]**	**F6[7.4]**
1	EU (.87)	TL (.72)	RY (.86)	GR (.83)	AM(.79)	CK (.68)
2	WU (.85)	MT (.69)	TN (.80)	SK (.70)	SW(.73)	GW (.53)
3	UT (.83)	KG (.65)	WR (.70	ER (.63)	AP (.70)	JH (.50)
4	HP (.73)	VD (.64)	CA (.67)	MM (.60)	NM (.61)	OR (.42)
5	BH (.71)	KR (.62)	PJ (.60)	WM (.59)	BH (.29)	NI (.39)
Components	RFJL(July) Initial Eigen value (cumulative) = 62.03, Rotated sum of squares (cumulative) =67.03, KMO = 0.52					
Factor (F)	**F1 [15.9]**	**F2 [15.3]**	**F3 [10.9]**	**F4 [9.2]**	**F5 [8.7]**	**F6[7.0]**
1	CH (0.74)	RY (0.87)	HC (0.87)	KR (0.77)	EU (0.83)	KG (0.48)
2	OR (0.70)	CA (0.86)	PJ (0.76)	CK (0.70)	BH (0.77)	VD (0.45)
3	WM (0.63)	TL (0.81)	WR (0.65)	SI (0.68)	AM (0.55)	MT (0.41)
4	VD (0.61)	NI (0.69)	WU (0.63)	LD(0.64)	JH (0.52)	TL (0.35)
5	EM (0.57)	MT (0.66)	HP (0.54)	MH (0.58)	WU (.50)	MM (.34)
Components	RFAG (August) Initial Eigen value (cumulative) = 66.78, Rotated sum of squares (cumulative) =71.40, KMO = 0.59					
Factor (F)	**F1 [14.8]**	**F2 [14.6]**	**F3 [14.3]**	**F4 [11.5]**	**F5 [11.0]**	**F6[5.2]**
1	SW(.80)	WU (.88)	GR (.87)	LA (.82)	MT (.71)	JK (.70)
2	AP (.78)	HD (.86)	MM (.73)	KR (.82)	TL (.67)	TN (.57)
3	BH (.70)	PJ (.80)	SK (.70)	SI (.74)	CA (.67)	RY (.37)
4	RY(.69)	HP (.69)	KG (.67)	CK (.70)	VD (.56)	CA (.26)
5	NI (.65)	EU (.59)	WR (.65)	AN (.60)	NM (.36)	PJ (.24)
Components	RFSP (SEPTEMBER) Initial Eigen value (cumulative) = 69.96, Rotated sum of squares (cumulative) =71.13, KMO = 0.60					
Factor (F)	**F1 [17.6]**	**F2 [17.0]**	**F3 [11.1]**	**F4 [10.5]**	**F5 [7.6]**	**F6[7.3]**
1	NI (.90)	SK (.77)	WU (.81)	HCD (.88)	JH (.85)	AM (.80)
2	MM (.83)	GR (.75)	UT (.73)	PJ (.86)	BH (.76)	SW(.67)
3	RY (.78)	VD (.72)	EM (.72)	HP (.86)	GW (.73)	AP (.67)
4	MT (.75)	KG (.71)	EU (.68)	WU (.44)	SW(.44)	NM (.58)
5	KR (.75)	ER (.68)	WM (.48)	JK (.39)	WM (.21)	JK (.32)
Note: Values of square brackets are (%) variances in Rotation Sums of Squared Loadings. Values of Parenthesis are rotated components.						

Table 2b: Rotated Matrix from Factor Analysis of rainfall in 36 Met-regions in India- Top 6 factors and top 5 components (using Principal Component Analysis)- continued						
Components	RFOT(OCTOBER) Initial Eigen value (cumulative) =70.95 , Rotated sum of squares (cumulative) =75.71, KMO = 0.66					
Factor (F)	**F1 [16.2]**	**F2 [15.8]**	**F3 [15.1]**	**F4 [13.5]**	**F5 [9.3]**	**F6[5.8]**
1	PJ (.94)	CH (.84)	EU (.87)	KG (.74)	KR (.87)	AM (.73)
2	HC (.93)	TL (.79)	BH (.70)	MM (.73)	LA (.77)	NM (.62)
3	WR (.79)	CA (.74)	EM (.68)	NI (.70)	TN (.74)	AP (.61)
4	HP (.75)	OR (.72)	WU (.68)	MT (.68)	SI (.70)	GW (.55)
5	UT (.64)	GW (.65)	WM (.67)	CK (.63)	CK (.46)	SW (.50)
Components	RFNV (NOVEMBER) Initial Eigen value (cumulative) = 73.74, Rotated sum of squares (cumulative) =78.85, KMO = 0.69					
Factor (F)	**F1 [26.4]**	**F2 [13.4]**	**F3 [12.4]**	**F4 [11.4]**	**F5 [8.7]**	**F6[6.6]**
1	NI (.85)	SK (.90)	HP (.92)	GW (.89)	EU (.70)	SW(.54)
2	CK (.84)	ER (.90)	UT (.89)	NM (.82)	BH (.66)	AM (.54)
3	CA (.83)	GR (.90)	PJ (.80)	OR (.78)	EM (.64)	LA (.50)
4	SI (.83)	WM (.65)	JK (.59)	JH (.77)	CH (.50)	AP (.50)
5	VD (.81)	WR (.60)	HCD (.59)	AM (.57)	JH (.43)	TN (.34)
Components	RFDC (DECEMBER) Initial Eigen value (cumulative) =73.37 , Rotated sum of squares (cumulative) =77.57, KMO = 0.65					
Factor (F)	**F1 [22.6)**	**F2 [14.6]**	**F3 [12.2]**	**F4 [12.2]**	**F5 [11.0]**	**F6[5.0]**
1	CH (.91)	SI (.90)	HP (.89)	AM (.86)	WR (.88)	AN (.68)
2	EM (.88)	KR (.83)	JK (.76)	GW (.79)	GR (.87)	CA (.49)
3	VD (.84)	TN (.83)	UT (.75)	SH (.78)	SK (.81)	TL (.46)
4	EU (.79)	RY (.81)	PJ (.72)	AP (.70)	ER (.68)	OR (.42)
5	WM (.77)	CK (.74)	HCD(.71)	NM (.69)	KG (.64)	NM (.22)
Note: Values of square brackets are % of variances in Rotation Sums of Squared Loadings. Values of Parenthesis are rotated components.						

Table 3a: Regression of Sectoral-GDP (SGDP) in agriculture (AFFMQ) and Manufacturing (MCEGW) using rainfall dimensions from Factor Analysis only					
		AFFMQ		MCEGW	
Variables	Lag	Co-eff.	t-stat.	Co-eff.	t-stat.
Constant		123.00	30.90***	-21.07	-1.91
AFFMQ	1	0.001	9.05***	0.002	24.16***
Price					
WPI-all	1	-5.80	-12.49 ***	-	-
WPI-electricity & fuel	0	-6.51	-33.31***	-	-
WPI-electricity	0	-	-	10.12	6.55***
WPI-fuel	0	-	-	-2.87	-6.05***
WPI-food article	2	0.89	2.37**	-18.07	-9.52***
WPI-food product	0	3.65	8.89***	-	-
WPI-food product	2	-	-	8.52	3.67***
WPI-pesticides	0	-2.24	-12.34***	-	-
WPI-cement	3	-	-	2.46	1.74*
WPI-metal	2	-	-	-2.78	-2.64**
WPI-metal	3	-1.53	-6.76	-	-
Administration/Policy					
Bond-Rate	3	-	-	-13.40	-2.22**
Bond-Rate	4	-23.50	-18.62***	-	-
Exch-Rate(INR/USD)	3	1.25	2.71***	-	-
Exch-Rate(INR/USD)	4	-	-	-11.21	-5.89***
Ag. Credit	1	-	-	0.04	8.47***
Ag. Credit	2	0.01	9.89***	-	-
Food-Procurement	1+2	2.32	15.53***	-	-
Rainfall Factors (F)					
June-F(5)	0	-29.44	-19.05***	-16.20	-2.71***
June-F(5)	1	-21.62	-17.56***	-	-
July-F(5)	0	2.28	1.85*	-	-
July-F(2)	1	12.90	11.67***	-	-
July-F(4)	0	-	-	23.83	3.47***
July-F(4)	1	-	-	-29.95	-5.29***
Aug-F(4)	0	14.87	13.00***	-20.35	3.28***
Oct-F(3)	1	-6.11	-4.91***	-	-
Nov-F(1)	1	16.58	14.55***	-	-
Nov-(F2)	1	54.95	16.27***	-	-
R-Square		0.99		0.98	
RMSE (%)		4.2		14.7	
Sample size (years)		32		32	
Note: Instruments: All price are regressed on past 4 past values. *, ** and *** represents level of significance at 10%, 5% and 1%. Factor *F(n)* is n-th Factor of rainfall for the month. Up to 6 Factors are used.					

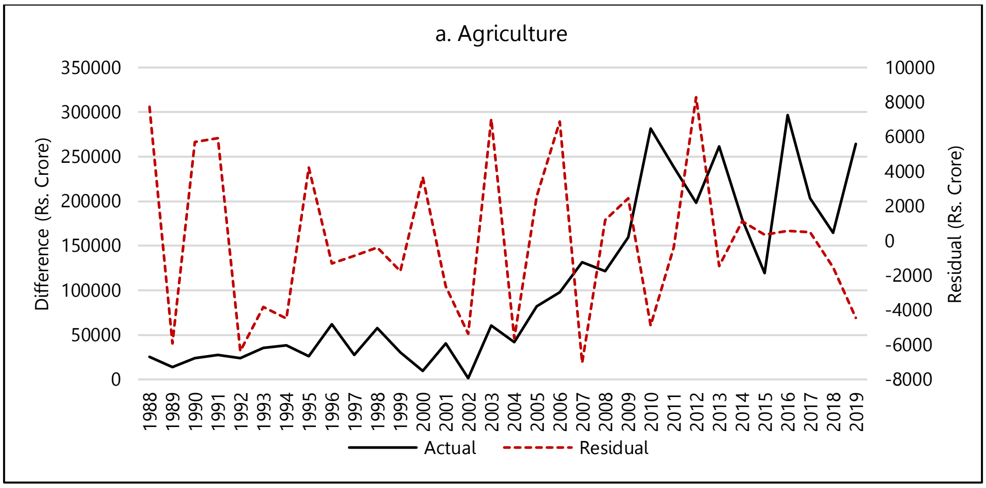
Table 3b: Regression of Sectoral-GDP (SGDP) in agriculture (AFFMQ) and Manufacturing (MCEGW) using rainfall dimensions from Factor Analysis and also from reported METs that are not included in Factor analysis.					
		AFFMQ		MCEGW	
Variables	Lag	Co-eff.	t-stat.	Co-eff.	t-stat.
Constant		115.19	20.68***	-40.64	-2.31**
AFFMQ	1	0.001	10.08***	0.002	27.52***
Price					
WPI-All	1	-6.21	-19.84 ***	-	-
WPI-Electricity & Fuel	0	-6.53	-40.38***	-	-
WPI-Electricity	0	-	-	12.70	9.07***
WPI-Fuel	0	-	-	-3.14	-8.04***
WPI-Food	2	1.62	5.93***	-17.31	-9.79***
WPI-Food Product	0	4.09	15.31***	-	-
WPI-Food Product	2	-	-	4.36	1.94*
WPI_Pesticides	0	-2.72	-18.27***	-	-
WPI-Cement	3	-	-	3.12	2.72***
WPI-Metal	2	-	-	-2.88	-3.47**
WPI-Metal	3	-1.29	-8.50	-	-
Administration/Policy					
Bond Rate	3	-	-	-19.89	-4.12***
Bond Rate	4	-22.20	-20.26***	-	-
Dollar Exchange Rate(INR/USD)	3	1.99	6.40***	-	-
Dollar Exchange Rate(INR/USD)	4	-	-	-8.63	-5.48***
Ag. Credit	1	-	-	0.04	7.92***
Ag. Credit	2	0.01	16.82***	-	-
FG-Procurement	1+2	2.45	21.90***	-	-
Rainfall Factors (F)					
June-(F5)	0	-31.97	-27.07***	-11.60	-2.31**
June-(F5)	1	-19.59	-21.50***	-	-
July-F(5)	0	2.70	2.26**	-	-
July-F(2)	1	14.33	17.04***	-	-
July-F(4)	0	-	-	31.18	5.40***
July-F(4)	1	-	-	-31.67	-6.62***
Aug-F(4)	0	15.65	20.12***	-23.69	4.79***
Oct-F(3)	1	-11.94	-15.89***	-	-
Nov-F(1)	1	16.28	19.93***	-	-
Nov-F(2)	1	52.74	24.09***	-	-
Rainfall MET regions					
June-JK	0	0.09	4.12***	-0.24	-2.34**
June – SI	0	0.04	2.37**	-	-
Sep – OR	0	0.03	2,39**	-	-
Sep _ OR	1	-0.05	-4.37***	0.10	1.99**
R-Square		0.99		0.98	
Sample Size (years)		32		32	
Note: Instruments: All price are regressed on past 4 past values. *, ** and *** represents level of significance at 10%, 5% and 1%. Factor *F(n)* is n-th Factor of rainfall for the month. Up to 6 Factors are used. MET region rainfall represented by *Month-MET* (see Table1 for abbreviations)					

Table 4: Communalities for Monthly rainfall in meteorological region of India

MET	May	MET	June	MET	July	MET	Aug	MET	Sep	MET	Oct	MET	Nov	MET	Dec
CK	0.91	RY	0.81	HD	0.85	GR	0.85	HD	0.89	PJ	0.92	ER	0.94	EU	0.92
VD	0.90	WM	0.80	RY	0.85	WU	0.83	NI	0.87	WU	0.92	EU	0.93	CH	0.91
TL	0.90	EU	0.77	MM	0.81	WM	0.82	WU	0.86	HD	0.90	GR	0.91	EM	0.88
MT	0.86	CA	0.75	CA	0.79	RY	0.82	HP	0.81	EU	0.85	WM	0.90	WU	0.86
KG	0.86	WU	0.74	WU	0.78	ER	0.79	JH	0.81	WR	0.84	PJ	0.90	SI	0.85
KL	0.84	EM	0.74	TL	0.78	CA	0.78	MM	0.79	WM	0.83	SK	0.90	BH	0.85
LD	0.83	CH	0.74	EU	0.78	KG	0.77	PJ	0.79	TL	0.83	HP	0.89	HP	0.84
CA	0.83	UT	0.73	AM	0.77	TN	0.76	KG	0.79	KL	0.81	NI	0.87	HD	0.84
HP	0.82	BH	0.73	JH	0.76	LD	0.76	VD	0.77	UT	0.81	GW	0.84	OR	0.84
WM	0.82	JH	0.73	BH	0.74	KL	0.76	BH	0.74	VD	0.80	BH	0.83	GR	0.83
WU	0.81	VD	0.72	KG	0.73	MM	0.76	KL	0.73	GW	0.79	UT	0.82	KG	0.83
GW	0.80	OR	0.71	VD	0.72	SW	0.76	WM	0.73	NI	0.77	EM	0.82	PJ	0.83
PJ	0.80	AM	0.70	KL	0.69	TL	0.76	SW	0.72	OR	0.77	CH	0.81	VD	0.81
ER	0.79	GR	0.70	SI	0.68	HD	0.75	AM	0.71	CH	0.76	MM	0.81	WR	0.80
EM	0.78	WR	0.70	SW	0.66	MT	0.75	EM	0.71	HP	0.76	VD	0.81	WM	0.80
HD	0.77	TN	0.70	CH	0.65	AR	0.75	MT	0.70	MT	0.76	JH	0.81	KL	0.78
NI	0.77	MM	0.68	ER	0.65	JH	0.74	RY	0.70	BH	0.76	WU	0.79	MT	0.78
RY	0.76	HP	0.68	PJ	0.64	SI	0.73	UT	0.69	EM	0.75	CA	0.78	AM	0.78
EU	0.76	GW	0.67	LD	0.63	PJ	0.72	ER	0.67	CA	0.73	CK	0.78	UT	0.78
CH	0.74	KL	0.66	MT	0.62	CK	0.71	SK	0.67	ER	0.73	KG	0.78	SW	0.77
AM	0.73	PJ	0.64	CK	0.61	GW	0.71	EU	0.66	GR	0.72	OR	0.77	TN	0.76
TN	0.73	ER	0.64	NI	0.60	EM	0.69	TL	0.65	SK	0.70	WR	0.76	TL	0.74
JH	0.72	MT	0.64	GW	0.60	WR	0.68	GR	0.64	SI	0.69	MT	0.75	CK	0.74
UT	0.71	TL	0.63	AR	0.59	BH	0.65	CH	0.63	CK	0.69	TL	0.74	ER	0.74
OR	0.70	HD	0.62	HP	0.57	AM	0.65	JK	0.60	MM	0.68	SI	0.73	CA	0.73
MM	0.68	SW	0.62	OR	0.57	VD	0.63	AR	0.60	TN	0.68	EH	0.72	AR	0.73
SI	0.67	NI	0.59	GR	0.56	SK	0.63	GW	0.57	JH	0.67	HD	0.71	MM	0.72
BH	0.65	AR	0.56	JK	0.56	NI	0.61	LD	0.55	JK	0.65	TN	0.71	GW	0.72
JK	0.63	CK	0.55	EM	0.56	JK	0.61	WR	0.55	LD	0.65	KL	0.70	RY	0.69
SW	0.61	AN	0.55	SK	0.53	CH	0.58	SI	0.54	KG	0.64	LD	0.68	SK	0.69
WR	0.59	SK	0.55	WR	0.52	HP	0.52	AN	0.51	AM	0.63	AM	0.64	NI	0.67
AR	0.58	KG	0.55	TN	0.51	EU	0.51	CA	0.48	SW	0.62	RY	0.60	AN	0.65
EH	0.56	JK	0.47	WM	0.51	OR	0.50	OR	0.43	RY	0.55	SW	0.59	JK	0.63
AN	0.56	EH	0.46	UT	0.50	AN	0.49	TN	0.42	EH	0.43	AR	0.54	JH	0.63
GR	0.56	LD	0.40	EH	0.42	UT	0.32	EH	0.40	AR	0.41	JK	0.44	EH	0.58
SK	0.46	SI	0.39	AN	0.37	EH	0.24	CK	0.34	AN	0.33	AN	0.35	LD	0.39

Note: Based on Principal Components Analysis (PCA) using Stata. Highlighted regions are excluded in PCA analysis due to low communality.

Table 5: Contributions of aggregated groups of explanatory variables to Estimated SGDP (%)						
	SGDP levels of years			SGDP change over years (periods)		
AFFMQ (Agriculture)						
Year	2010-11	2015-16	2019-20	P-1	P-2	P-Overall
Constant	45	105	47	0	0	0
Agri_gdp (-1)	14	36	15	-3	-3	-8
Prices	3	15	-11	-7	-32	231
Administrative policies	16	-82	25	90	113	-126
Rainfall	22	26	24	20	21	3
Dependent (Rs. '000 Crore)	275	118	260	-157	142	-15
MCEGW (Industry)						
Constant	-12	-7	-8	0	0	0
Agri_gdp (-1)	195	118	125	22	81	-12
Prices	-52	-9	-7	43	-22	81
Administrative policies	-24	-3	1	22	-28	50
Rainfall	-8	2	-12	13	69	-19
Dependent (Rs. '000 Crore)	169	306	256	136	-50	86
Note: P1= 2010-11 – 2015-16, P2=2015-16 – 2019-20, P-Overall=2010-11 – 2019-20. Variables other than rainfall are in first difference.						



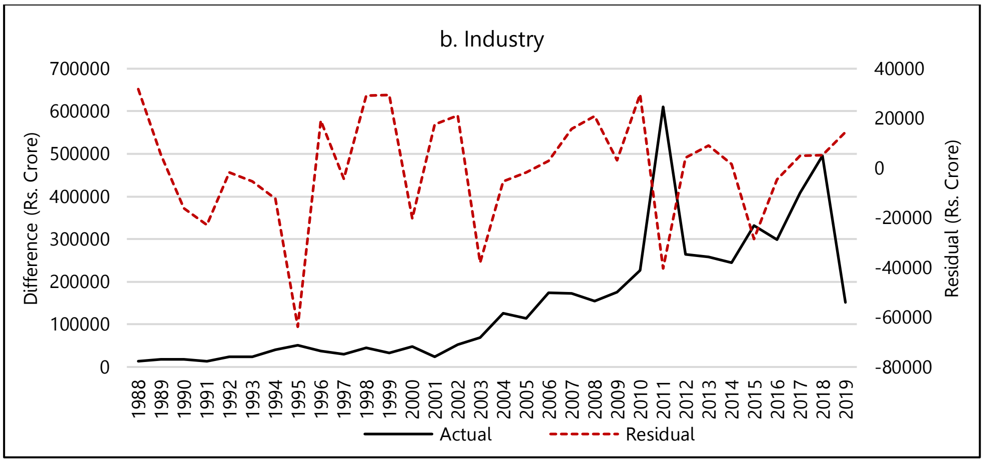


Figure 1: Actual and Residual for SGDP in first difference

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