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Article · October 2020

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Journal of Management Outlook
Volume 10, No. 1• January-June 2020

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Keywords: *Monsoon, Economy, Sectoral, Growth, Demand*

Abstract

Monsoon influence on the farm economy is well known. However, through demand and supply interlinkages of farm sector with other sectors of the economy, monsoon is seen to have a significant influence on the standard of living and overall demand in the economy. Most importantly, spatial distribution of monsoon has emerged as the key factor influencing economic activity. Good monsoon in agriculture dominated states influence not only farm economy but also the non-farm sectors. Electricity, Gas and Water Supply being the most significant of all. This is because of increasing demand for water to generate electricity. A positive influence of good monsoon is also evident in Trade, Transport, Storage and Communication, Banking and Insurance and Manufacturing sector. Growth in agricultural output produces strong demand incentives in the form of increased rural demand, which fosters expansion in various sectors of the economy.

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Introduction

Policymakers across the globe are increasingly concerned about the economic effects of climate change (Brown et al. 2011). Sea level rise of several meters and major disruption to monsoon rains and river flows in India are among the biggest global economic risks from climate change (Grantham Research Institute on Climate Change and the Environment,2019). Existing literature suggests, increase in temperature has a negative effect on economic growth while rainfall could have both positive (Brown et al. 2013; Odusola and Abidoye 2015) and negative effects (Dell et al. 2012; Tebaldi and Beaudin 2016).

In India, the impact of monsoon variability on agricultural production and economy of India is well known. Consequently, considerable efforts are being made to predict monsoon on a real time basis and adopt strategies to cope up with the vagaries of monsoon. However, the Grantham Research Institute on Climate Change and the Environment in its policy report highlighted that climate change is likely to mean monsoon systems affect larger areas over longer time scales, and rainfall during monsoon season is likely to intensify while becoming less predictable. The largest effect, which is already being observed today, is an increase in the year-to-year variability of the monsoon strength and the associated extremes of rainfall". (UN climate summit report, reported in Hindustan Times, 21st Sept, 2019.).

In this context, it has become even more crucial to understand the effects of monsoon on economic growth so as to enable the

Journal of Management Outlook
Volume 10, No. 1 • January-June 2020

policy makers effectively support and evaluate climate change policy. Existing literature on monsoon has a huge focus on impact of rainfall on poor, agricultural-based economies (Gadgil and Gadgil 2006; Gilmont et al. 2018). Henseler and Schumacher (2019) provided evidence of a wider perspective by assuming that the GDP was a function of the climatic variables. According to Becken and Wilson (2013), extreme rainfall and drought influenced the profitability and popularity of the tourism sector in New Zealand. In addition, countries that are reliant on hydroelectricity or other types of water energy production are heavily dependent on adequate annual rainfall (Solaun and Cerdá 2017). In terms of economic activity, Jones and Olken (2010), who considered the losses in industrial output by examining a global sample of trade data, found that for each 1?C of warming, poor countries faced an average 2.4% decline in exports.

The purpose of this study is to investigate monsoon variability and its impact on standard of living and demand. Demand in any economy is influenced by economic activity in different sectors. In this paper, we have looked at the impact of monsoon changes on the standard of living and demand through two proxy indicators, i.e., Per Capita Income (PCI) and Private Final Consumption Expenditure (PFCE). Further, this paper also evaluates the impact of monsoon on different sectors of the economy, i.e., agriculture, industry, and services which have an important bearing on the per capital income and expenditure in the economy.

The paper is structured in the following manner. In the following section, we discuss the monsoon trend in India in the last 50 years. Section 3 discusses the relationship between weather variables and economic indicators. Section 4 concludes the paper.

Section 2: Monsoon Pattern Since 1960

India has a tropical monsoon climate and rainfall is an important element for the economy. Traditionally Indian monsoon season is between June 1st to September 30th. The June-Sept rains (or South-West Monsoon Rains) account for nearly 76 percent of the annual precipitation and more than half of the total cultivated area is dependent on these rains. The rainfall season between the months of October-December is known as the North-East monsoon season. The south Peninsular India consisting of five sub-divisions (Tamil Nadu, Coastal Andhra Pradesh, Rayalaseema, Kerala and south-interior Karnataka) receive about 30% of its annual rainfall during this season (Gulati, et, al, 2013.

As defined by the Indian Meteorological Department (IMD), when rainfall for the monsoon season of June to September for the country as a whole is within 10 percent of its long period average (LPA), it is categorized as 'normal monsoon'. When the monsoon rainfall deficiency exceeds 10 percent and affects more than 20 percent of the country's area, it is categorized as an "All-India drought year". The LPA is the average or normal rainfall value calculated for all-India or for smaller areas based on an average of actual rainfall received between 1951 and 2000; all-India LPA for monsoon rains is 886.9 mm or 89 cm (IMD, 2020).

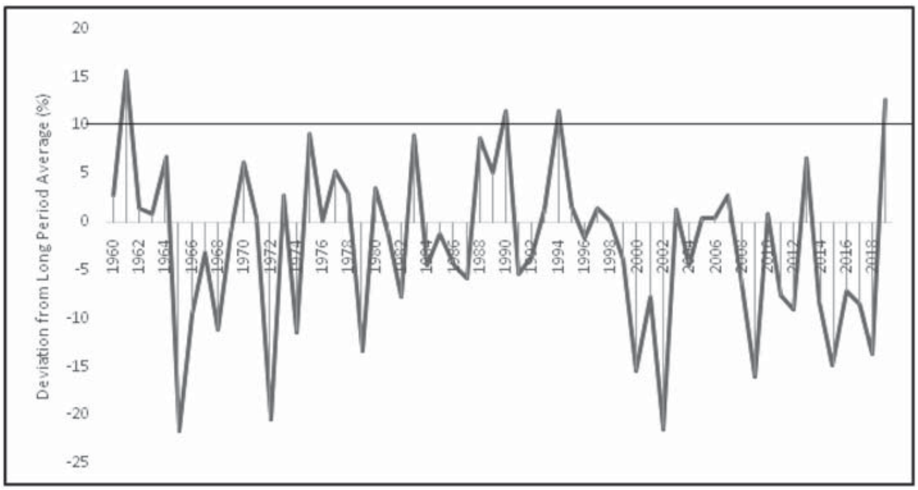
The performance of monsoons over the smaller areas of the country is similarly evaluated based on the deviation of their actual rainfall from the normal values, using the following criterion:

- **Excess Rains -** when the rainfall deviation for an area is + 20% and more, the area has 'excess rains'

- **Normal -** when the deviation is + 19%, the rainfall for the area is called normal.
- **Deficient -** Negative deviation of rainfall of equal to and greater than 20% but less than 26% is called "deficient" rainfall.
- **Drought -** If for an area the rainfall falls equal to or greater than 26% from its LPA value but less than 46%, drought is declared for the area. A fall of equal to or more than 46% implies the area is struck with severe drought (IMD, 2020).

A study of the rainfall trends shows that in the last 60 years, i.e., since 1960-61, there were about 10 occurrences of drought and 4 occurrences of flood. Since 1960, in every decade there has been at least 2-3 years of drought / flood. In the last 9 years, we have experienced drought in 2015 and 2018 and excess rains in 2019.

Fig 1: Trend in Monsoon: 1960 - 2019



Source: Indian Meteorological Department

A striking characteristic of the monsoon in India is its high variability. Monsoon failure is experienced in some part of the country almost every year. The long-term trend shows that drought is experienced once in every 5 years in all the states apart from North East. The periodicity of drought is as high as once in 3 years in states like Rajasthan, Andhra Pradesh, Haryana, Tamil Nadu, Gujarat, Jammu & Kashmir and West Uttar Pradesh.

Journal of Management Outlook
Volume 10, No. 1 • January-June 2020

Table 1: Periodicity of Drought

Frequency of drought	*Meteorological Sub-Division*
Once in 2.5 years	West Rajasthan, Rayalaseema, Telangana, Haryana, Chandigarh and Delhi
Once in 3 years	East Rajasthan, Gujarat Region, Jammu & Kashmir, Tamil Nadu and Puducherry, West Uttar Pradesh
Once in 4 years	North Interior Karnataka, Uttarakhand, Vidarbha
Once in 5 years	Bihar, Coastal Andhra Pradesh, East UP, Gangetic West Bengal, Jharkhand, Kerala, Odisha, South Interior Karnataka, Madhya Maharashtra, West Madhya Pradesh

Source: Crisis Management Plan, Drought Management Division, Ministry of Agriculture, GoI

In order to study the intensity of rainfall for each state, we have looked at the average rainfall received during 1989 to 2018. Monsoon variability is measured in terms of coefficient of variation (COV), i.e.,

Monsoon variability = (Standard deviation / Mean) * 100 …………… (i)

Evident from the table below, the eastern states, i.e., West Bengal, Orissa and Chhattisgarh are high in monsoon intensity and low in variability. Maharashtra is though, high in intensity but variability is also very high. Further, with only 20% of the cropped land irrigated, the state is highly vulnerable to monsoon. At the other end, states like, Punjab, Haryana and Uttar Pradesh are low in monsoon intensity and high in variability. However, high irrigation coverage, makes these states less vulnerable to monsoon. Gujarat, Andhra Pradesh and Rajasthan also fall in the category of low intensity and high variability. Despite this, just close to 50% of the cropped land is irrigated which makes it highly vulnerable to monsoon vagaries.

Table 2: State wise Monsoon Intensity and Monsoon Variability

States	*Rainfall Mean and Variability: 1989 - 2018*		*% of cropped area irrigated*
	CV	*Mean*	
KER	19.1	1955	18.4
WB	13.9	1419	64.0
UTK	18.5	1386	50.0
ODI	14.9	1160	29.9
CHH	15.3	1124	31.1
MAH	25.6	1021	20.2
JHA	18.7	1019	13.0
BIH	19.3	939	69.3
MP	18	921	42.3

States	*Rainfall Mean and Variability: 1989 - 2018*		*% of cropped area irrigated*
	CV	*Mean*	
KAR	14.5	847	31.2
TEL	22.5	713	41.4
HP	19.6	710	22.1
UP	18.7	697	80.2
GUJ	31.7	695	52.4
AP	21.2	513	47.1
PUN	28.8	428	98.6
RAJ	25.5	414	42.2
HAR	31	411	91.4
TN	26.3	312	58.8

Source: IMD

In the recent years, the effect of monsoon failure is also seen strongly in the irrigated areas where the water table has gone down due to over exploitation and where water supply in surface irrigation sources, like, canals and tanks depend on rains. The failure of the North East Monsoon in the southern states, particularly, Tamil Nadu has led to severe depletion in the reservoir levels.

Section 3: Monsoon and Economic Growth

The theoretical connection between economic growth and climate change has been exhibited through macroeconomic and microeconomic dimensions (Abidoye and Odusola 2015). For the macroeconomic aspect, the influence has been seen on the level output; such as, agricultural yields and economy's ability to grow. From the analysis of the microeconomic dimension, the linkage contain an array of factors; such as, physical and cognitive labour productivity, conflict, health and democratisation; all of which have economy-wide implications (Burke and Leigh 2010; Gallup et al. 1999; The Intergovernmental Panel on Climate Change (IPCC) 2007a). This paper uses the theoretical framework established in Sankhaphan and shu, 2019, to show the linkage between economic growth and climate variables, with variable of interest being rainfall.

In this paper, we attempt to see if the disruptions in economic growth due to monsoon failures impact the standard of living and therefore demand. One of the closest proxy measures of standard of living is per capita income. Growth in private final consumption expenditure reflects demand in the economy. Evident from the table below, during 1960s, per capita income growth in drought years slowed down significantly as compared to a year before. Also, drought in 2000s saw a sharp drop in per capita income growth. However, in the recent years, the effect of drought on per capita income has become less evident. Likewise, during 1960s, there was a sharp drop in consumption expenditure growth in the drought years. A similar pattern was evident in the early

2000s. The recent years have seen more resilience to drought. One obvious reason is that there are host of factors that impact the income and expenditure levels. For instance, growth in per capita income and consumption in the drought year of 2009 can be linked to several support measures provided by the government in the rural areas, like, hike in Minimum Support Prices, Farm loan waivers etc.

Table 3: Per Capita Income Growth in Drought Years

Drought years (t)	*Per Capita Income Growth (t)*	*Per Capita Income Growth (t-1)*
1965	3.4	14.2
1968	3.8	14.7
1972	7.7	4.8
1974	15.5	19.0
1979	7.9	5.9
2000	5.5	10.5
2002	6.1	6.9
2009	14.1	11.02
2015	9.0	9.50
2018	10.1	9.88

Table 4: Private Final Consumption Expenditure Growth in Drought Years

Drought years (t)	Private Final Consumption Expenditure Growth (t)	Private Final Consumption Expenditure Growth (t-1)
1965	5.6	17.7
1968	0.0	19.2
1972	10.2	7.9
1974	21.2	20.6
1979	8.6	8.8
2000	7.2	12.5
2002	5.8	8.9
2009	14.0	14.4
2015	12.1	11.9
2018	11.5	10.6

However, most importantly, there has been significant changes in the structure of the economy at a micro level since 1960s. Some economies are more resilient due to higher irrigation coverage, higher diversification of income and lower dependence of agriculture. Monsoon failure in these economies have a lower impact on agriculture. For instance, after green revolution in 1960s, more than 90% of the cropped land in Punjab and Haryana are under irrigation coverage. Therefore, monsoon failure in one year may not have a direct impact on the income levels in that year, but continuous 2 years of dry spell may deplete the reservoir levels. Similarly, the economies that are less dependent on agricultural income and have diversified income, like, Maharashtra, Tamil Nadu are likely to have lower impact of drought or flood on the overall economic growth. Role of government in the recent years has increased significantly in influencing demand. Even, in the drought years, PFCE recorded a double-digit growth. There is rich literature suggesting that enhanced government expenditure on rural public goods contributes strongly to agricultural growth across regions although with varying degree. Further, rural public goods are complementary to private on-farm investment; investing in former often enhances investments in the other by creating enabling environment (Singh et,al, 2015), The increased government spending in rural goods have led to higher agricultural growth in states, like Madhya Pradesh and Gujarat making these economies more resilient to drought or flood as compared to others.

Accordingly, it is important to identify the impact of monsoon failures on the income and expenditure with all the structural changes in the economy at a micro level. While role of government spending in influencing demand over the years have increased, the increased spending gets reflected in the economic growth of the state or agricultural dominance. Hence, government spending is not taken separately in the empirical model. We have looked at it in two stages. Firstly, an empirical model is defined to estimate the impact of climate variables on the per capita income and consumption expenditure using panel data of 50 years and 35 states. In the second stage, used the same empirical model to define the impact of monsoon variability on sectoral GDP.

The empirical model for measuring the impact of climate variables on Per Capita Income:

$$\mathbf{pci\ i, t = \Upsilon 0X + \Upsilon i(pre * temp)i, t + \Upsilon 2(pre * agrist) + \Upsilon 3(prec * irrist) + \Upsilon 4(pre * poorst) + \alpha i + at + \varepsilon i, t \ldots\ldots\ (ii)}$$

Where,

- y= Per capita income in 'I_{th}' state and t_{th} time. (y- is the natural logarithm of per capita income)
- X = Dummy variable explaining the occurrence of flood or drought
- pre * temp = Interaction of average annual temperature and average annual rainfall
- pre*agrist = Interaction between rainfall and agriculture dominated states (defined in terms of contribution to All India agriculture GDP > 5%)
- pre*irrist = Interaction between rainfall and irrigation coverage of the states (defined in terms of irrigation coverage >80%)
- pre*poorst =Interaction between rainfall and poor economies (defined in terms of GDP contribution >5%)

- αi = State Fixed effect
- at=Time fixed effect
- εi,t= Unexplained residual

The empirical model for measuring the impact of climate variables on Private Final Consumption Expenditure is defines as follows:

$$\mathbf{pfce\ i, t = \Upsilon 0X + \Upsilon i(pre * temp)i, t + \Upsilon 2(pre * agrist) + \Upsilon 3(prec * irrist) + \Upsilon 4(pre * poorst) + \alpha i + at + \varepsilon i, t \ldots\ldots\ (ii)}$$

Where,

- pfce i, t= Private Final Consumption Expenditure in 'I_{th}' state and t_{th} time. (y- is the natural logarithm of per capita income)

Table 4: Estimates from Generalised Least Squares: 1960 - 2019

Dependent Variable: Per capita Income	*Coef.*	*Z*	*P>z*
Drought/ flood	-0.32	-0.63	0.029
Temperature * Precipitation	3.72	3.12	0.002
Precipitation in states with >80% irrigation coverage	- 0.08	-6.50	0.000
Precipitation in states with > 5% contribution to All India Agri GDP -	6.72	1.06	0.087
Precipitation in states with <5% contribution to total GDP	4.23	-1.96	0.050
_cons	-23.90	-1.35	0.176
Observations	2450		
Log Likelihood	134.8		

Note: Time and state fixed effects are included in the analysis, not reported; P>z defines the level of significance

The estimates from the Generalised Regression model clearly prove our hypothesis that increase in probability of flood or drought by 1 unit can reduce per capita income by 0.32%. The interactive variable- temperature and rainfall shows if temperature increase is coupled with the increase in precipitation by 1 unit, per capita income is likely to increase by 3%. However, the increase in temperature alone is likely to have a negative impact on per capita income (temperature was not found to be statistically insignificant in this model, hence not reported.).

Nevertheless, the analysis suggests that spatial distribution of rainfall is the most important determinant. Agriculture dominated states with contribution to All India GDP greater than 5% have a high positive influence of rainfall. 1 unit increase in precipitation within normal range in the agriculture dominated states can increase per capita income by ~7%. Further, poor economies with less than 5% contribution to All India GDP and high dependence on agriculture is likely to influence positive growth in per capita income

Table 5: Estimates from Generalised Least Squares: 1960 - 2019

Dependent Variable: Private Final Consumption Expenditure	*Coef.*	*Z*	*P>z*
Extreme events of Drought/ flood	-0.36	-0.62	0.03
Temperature * Precipitation	4.13	3.12	0.00
Precipitation in states with >80% irrigation coverage	-6.67	-6.42	0.00
Precipitation in states with > 5% contribution to All India Agri GDP -	2.94	1.04	0.30
Precipitation in states with <5% contribution to total GDP	-4.72	-1.97	0.05
_cons	-21.03	-1.07	0.28
Observations	2450		
Log Likelihood	134.8		

Note: Time and state fixed effects are included in the analysis, not reported; P>z defines the level of significance

The estimates from the Generalised Regression model with private final consumption expenditure as the dependent variable is largely similar to that of the income model. This is because monsoon shocks impact demand through its influence in economic activity. Clearly, extreme weather events, like, drought or flood has an adverse impact on per capita income and therefore expenditure. Again, spatial distribution of rainfall is clearly the most important determinant of expenditure growth.

As per the occupational distribution, more than 50 per cent of the population depend on agriculture as a primary occupation for their living. Thus, it is highly likely, that performance of agriculture sector would have influence on the PFCE. This also confirms with what RBI (2002) had noted that the output of agriculture sector is influenced by weather and not by market forces, and that its performance significantly influences the level of aggregate demand through its impact on private consumption expenditure.

The oldest theories of the business cycle link the causes of fluctuations in business cycle to meteorological conditions. Sunspot theory (originally proposed by William Stanley Jevons and later advanced by H. S. Jevons and H.L. Moore) establishes causal linkage between meteorological condition, which impacts agricultural activity, income and the economic activity. It is premised on the belief that the real cause of business cycle lies in variation in weather, which impacts the general economic activity (Raj et.al, 2016).

Following the work of Ragnar Frisch (1933) on the role of random shocks originating in agricultural sector in generating business cycles in India, Chitre and Paranjape (1987) decomposed growth cycle fluctuations in non-agricultural income of Indian economy into those emanating from the fluctuations in agricultural sector and other impulses. They showed that even if other shocks/ impulses were absent in the Indian economy, random uncorrelated shocks originating in agricultural sector can produced cyclical movement in non-agricultural sector (Chitre, 1990).

Clearly, the impact of weather variables on demand may not originate from agriculture alone but also other sectors of the economy. To identify the impact of weather variables on different sectors

Journal of Management Outlook
Volume 10, No. 1 • January-June 2020

of the economy we have used same the empirical model on a panel data set of 50 years and 35 states.

Table 6: Estimates from Generalised Least Squares: 1960 - 2019

	Agriculture & Allied		*Industry*				*Services*	
	Faming	*Fishing*	*Mining & Quarrying*	*Manufac-turing*	*Construction*	*Electricity, Gas & Water Supply*	*Trade, Transport, Storage & Communication*	*Finance & Insurance*
Drought/ flood	-3.46***	-0.32	-0.32	-0.47	-0.30**	-0.20**	-0.41**	-0.38
Temperature * Rainfall	6.95***	2.31*	0.31*	1.32**	1.77**	5.77**	1.0*	1.21**
Precipitation in states with >80% irrigation coverage	1.83*	0.87	0.07	-0.94	0.10	3.10*	0.79	-0.90
Precipitation in states with > 5% contribution to All India Agri GDP -	8.37	3.03	1.03**	1.77**	1.85**	6.67***	3.16**	3.00**
Constant	19.41	-35.06	-15.06	-33.52	-26.95	-16.95	-28.20	-30.33
Observations	2450	2450	2450	2450	2450	2450	2450	2450
Log likelihood	24.8	12.9	12.9	17.7	13.7	27.9	-8.9	7.2

Note: Time and state fixed effects are included in the analysis, not reported;
* Significant at 10% confidence interval, ** Significant at 5% confidence interval, *** Significant at 1% confidence interval.

The most direct impact of rainfall in any economy is certainly on the agriculture sector since water is an essential input for agricultural production. Drought or flood can reduce agriculture GDP growth by 3%. Moreover, compared to developed economies, poor economies with high dominance of agriculture and low irrigation coverage is likely to be more vulnerable to monsoon failures. However, it is also important to note that the agriculture sector is not just affected by the intensity and the spatial spread of rainfall but also on the timing of rainfall. The timing of the rain during critical growth periods is if not more, but equally important. The water support at strategic times may reduce or increase yield and quality of crops (Gulati, et. al, 2013). This analysis, however, do not consider the impact of timing of rainfall on the agriculture GDP.

Adverse impact of extreme weather events is also seen in the non-agricultural sectors but the extent of impact likely to be lower as compared to that of the Agriculture GDP. However, a positive influence of good monsoon within normal range is evident across all sectors of the economy. The most significant of these being electricity, gas and water supply. The generation of hydro-electric power from rainwater has been traced over the last 20 years. India is increasingly investing in renewable technology to meet rising energy demands, with hydropower and other renewables comprising one-third of current installed capacity. However, renewable electricity generation is dependent upon the prevailing meteorology, which is strongly influenced by monsoon variability (Dunning et.al, 2002). Our estimates suggest, an increase in rainfall by 1 unit within normal range can increase GDP from electricity, gas and water supply by 6%. The impact is evidently high in the agriculture dominated states where demand for power generation for irrigation purposes in good monsoon years are high.

A positive impact of good monsoon is also seen in other non-agricultural sectors of the economy. Mall (2001) had argued that growth in agricultural output produces strong demand incentives, by and large, in the form of increased rural demand, which fosters expansion in various sectors of the economy. Our estimates suggest, good monsoon at an overall level within normal range can increase GDP from transport, storage, trade and communication sector by 1% while the probability increases to 3% with good monsoon in the agriculturally dominated states. Also, GDP from finance and insurance sector is likely to increase by ~1% with good monsoon at an aggregate level and the probability of increase goes up to 3% with good monsoon in the agriculture dominated states. Similar impact is also evident in the construction and manufacturing sector.

Conclusion

Monsoon influence on the farm economy is well known. However, through demand and supply interlinkages of farm sector with other sectors of the economy, monsoon is seen to have a significant influence on the standard of living and overall demand in the economy.

We have used two proxy indicators, i.e., per capita income to measure the standard of living and private final consumption expenditure to measure demand in the economy. At a macro level, the influence of rainfall on per capita income and private final consumption expenditure is seen to have diminished over the years. However, this is because, at a micro level there has been significant changes in the structure of the economy. As a result, some economies have become more resilient as compared to others. For instance, Punjab and Haryana, with high irrigation coverage are agriculturally more resilient, while Tamil Nadu and Maharashtra with other developed sectors are economically more resilient. As a result, monsoon failures in these economies have a lower impact on the economic activity as compared to others. Thus, spatial distribution of monsoon emerges as the key factor influencing economic activity. Further, increasing government expenditure either in creating rural public goods or direct cash transfer played a significant role in making the agricultural economies resilient although at a varying degree.

Influence of monsoon is also seen in the non-farm sectors. Electricity, Gas and Water Supply being the most significant of all. This is because of the increasing use of renewable electricity generation, which is heavily dependent upon the prevailing meteorology, that is strongly influenced by monsoon. Though extreme events of drought or flood have less influence on the non-farm sectors, but good monsoon within a normal range is seen to have a strong positive influence on demand.

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Journal of Management Outlook
Volume 10, No. 1 • January-June 2020

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