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Trade-off between risk and returns in farmers' choice of crops? Evidence from India

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Abstract This paper has assessed variation in the exposure and vulnerability of crops to production risks such as droughts, floods and pests; and subsequently the trade-off between risk and returns in farmers' choice of crops. Findings show that, at any point of time, about one-third of the farm households are exposed to production risks and suffer a loss of about 12% in their potential farm returns. Drought accounts for about 47% of the total loss, followed by insect-pests (27%) and floods (20%). There is a considerable variation in exposure and vulnerability of crops to drought risk, but not much to flood and pest risks. The low-risk crops, mainly staple cereals, generate less but stable returns, and the crops that are more remunerative to produce are also more vulnerable to risks. In general, we find that risk-averse farmers choose low-return, low-risk crop portfolio, but those capable of bearing the cost of risks prefer a high-return, high-risk crop portfolio.

Keywords Production risks, returns, crop choice, trade-off, India

JEL classification Q01, Q12, Q54

1 Introduction

Agriculture inherently is a risky enterprise. It is exposed to several production risks such as droughts, floods, heat-stress, insect-pests and diseases that reduce not only its production potential but also incentives for farmers to adopt improved technologies and inputs and to invest in productive assets and human capital. It is now acknowledged that, in developing countries that heavily depend on agriculture and lack access to technologies, finances and institutions, farmers' frequent exposure to production risks is one of the major causes of low agricultural productivity, slow economic growth and persistent poverty (Dercon 1996; Bhandari et al. 2007; Carter et al. 2014; Kumar et al. 2014; Amare et al. 2018). Birthal et al. (2015a) have estimated on average 9% loss in paddy yield due to droughts. Bhandari et al. (2007) who investigated socio-economic consequences of droughts have reported a decline in household income by 25-60% and a rise in head-count poverty by 12-33% in the event of a drought. The most recent evidence shows that a reduction in rainfall by 20% may reduce domestic supplies of food grains by 8-21% and their demand by 5-14% (Kumar et al. 2014). Further, these studies also report that despite the use of adaptation measures, a majority of the farm households rarely recover fully the loss of productive assets such as livestock and land several years *ex post* the shock.

Managing agricultural risk is, therefore, crucial for securing livelihoods for agricultural populations, sustaining agricultural growth and avoiding poverty traps. There are several options to manage risk, *ex ante* and *ex post* the shock. Conditional on the severity of shock the farm households depending on their attitude toward risk and availability of resources can choose one or more options to manage risk. Often the risk-averse farmers, who anticipate occurrence of a shock and are constrained by a lack of access to formal credit markets and risk instruments, rely more on *ex ante* means to avoid adverse consequences of risk. They build up savings, accumulate assets, diversify economic

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activities, and choose crop portfolios that are less sensitive to climate extremes. In countries/regions, where formal markets for credit and insurance are under-developed or absent, farm households make adjustments within the cropping or production system (Jodha 1981; Walker & Jodha 1982; Walker & Ryan 1990; Jodha 1991; Reardon et al. 1992; Gadgil et al. 1988; Bromely & Chavas 1989; Rosenzweig & Binswanger 1993; Dercon 1996; Valdivia, et al. 1996; Seo & Mendelsohn 2008; Di Falco & Chavas 2009; Seo 2010; Macours et al. 2012). For example, they conserve moisture, change timing of sowing and other agricultural operations and choose a less risky crop portfolio. Crop diversification, however, is one of the widely used *ex ante* adaptation means to cope with production risks. Farmers choose a combination of crops with low correlated returns to spread risks across crops – if a crop does not perform well under risk, the loss in it, to an extent, can be compensated by the gains in another crop which can tolerate the risk better.

Nevertheless, the literature also reports a few limitations of crop diversification as a risk management strategy (see, Kimura et al. 2010; Khanal & Mishra 2017). One, the effectiveness of crop diversification as a risk-avoidance strategy would depend on the extent to which the chosen crops are risk independent. If the returns from chosen crops are strongly correlated, then the crop diversification cannot be an effective means of avoiding risk. Two, crop diversification means a re-allocation of resources, mainly land and water, across crops that differ in their yield potential as well as exposure to risk. This implies that there is an opportunity cost associated with diversification in terms of returns foregone from cultivation of more remunerative crops. Dercon (1996) has found that risk-averse Tanzanian farmers prefer cultivating low-risk, low-return crops so as to achieve a stable stream of income, essential for their consumption smoothening. Third, diversification in favor of more remunerative crops might involve fixed costs, the unit cost being higher at a smaller scale of production; hence the possibility of a conflict between scale and objectives of diversification cannot be ruled out. In this context, Birthal et al. (2015b) argue that high-value crops (i.e., vegetables, fruits, spices and plantation crops) though contribute to farm incomes and poverty reduction, yet their cultivation is limited to a small proportion of cropped area as well as households because of the higher fixed or start-up costs, and the production and market risks.

Crop diversification has been a common feature of farming systems in India's low-rainfall regions, but its importance in managing agricultural risks has remained under-researched, argue Jodha (1981), Ramaswami et al. (2003), Rathore (2004) and Khanal and Mishra (2017). In this paper, our main aim is to investigate trade-off between risks and returns in farmers' choice of crops. Towards this, first we analyse returns and riskiness of several crops or crop groups; and then show how farmers' exposure to risks can motivate them to make adjustment in their crop portfolios to manage risks or to enhance incomes. A better understanding of farmers' responses to climatic risks through adjustments in crop portfolios will provide policymakers and others important feedback for taking appropriate measures to help farmers cope with risks.

Rest of the paper is structured as follows. In section 2 we provide in brief the data sources and the preliminary statistics on crops' exposure and vulnerability to different production risks. Section 3 discusses the empirical approach employed to assess trade-off between risk and returns in farmers' choice of crops. The key findings regarding riskiness of crops and its association with the returns these generate are presented in section 4, and it is followed by a discussion of the findings in the light of existing literature in section 5. Concluding remarks are made in the last section.

2 Data and descriptive statistics

2.1 Data

To analyse the relationship between riskiness and returns in crop production, we make use of data generated through a nationally representative survey of farm households by the National Sample Survey Office (NSSO) of the Government of India (GoI 2015). This survey was conducted in 2012-13 with the aim of understanding economic status of farmers and farming in India. Unlike other farm surveys, this survey is unique in the sense that it contains information on downside risks, in terms of loss in crop outputs experienced by farm households due to natural hazards such as droughts, floods and pests. The survey contains information form 35200 farm households spread over 4529 villages in 566 districts across the country.

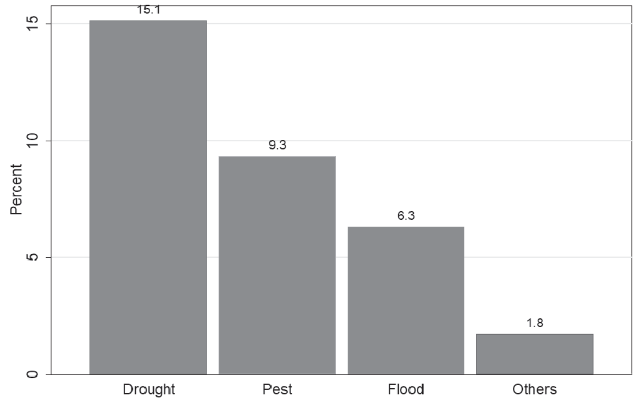

Figure 1. % farm households reporting crop loss due to different risks (%)

Besides information on crop-specific returns and loss, this survey also contains information on several aspects of farming (i.e., cropping pattern and crop yields), farmers (i.e., household income and its components, landholding size, land tenure, irrigated area, family size, social status and education level) and institutions (i.e., access to credit, information and markets), essential for understanding farmers' attitude toward risk in their choice of crops and adaptation strategies.

2.2 Descriptive statistics

Figure 1 shows farm households' exposure to different production risks, in terms of the proportion of total farm households reporting loss in crop output either due to droughts or floods or insect-pests or other factors such as fires and thefts. This distribution indicates that farmers are more exposed to drought risk – over 15% of them have reported loss in crop production due to droughts. Insect-pests comprise the second most important source of risk, and is followed by floods (6.3%). On the whole, at any point of time, about one-third of the farm households in the country are exposed to production risks and half of them to the drought risk.

A greater exposure of farmers to drought risk is because of occurrence of droughts on a larger geographical area — about two-third of the country's geographical area is prone to droughts (GoI 2009). Floods, on the other hand, are localized, often confined to high-rainfall regions, and affect only about 12% of the geographical area (GoI 2008). Note that, large scale droughts and floods represent systemic risk, and these, when occur, affect a large geographical area and population. Pest risk is often idiosyncratic; hence is manageable through technological and non-technological interventions at farm-level.

Next, we examine the exposure level of different crops to different production risks. Figure 2 presents farmers' responses to exposure of crops to different production risks. Cotton is more exposed to drought risk, as 31% of the cotton growers have reported droughts as the main cause of loss in its output. Coarse cereals (millets

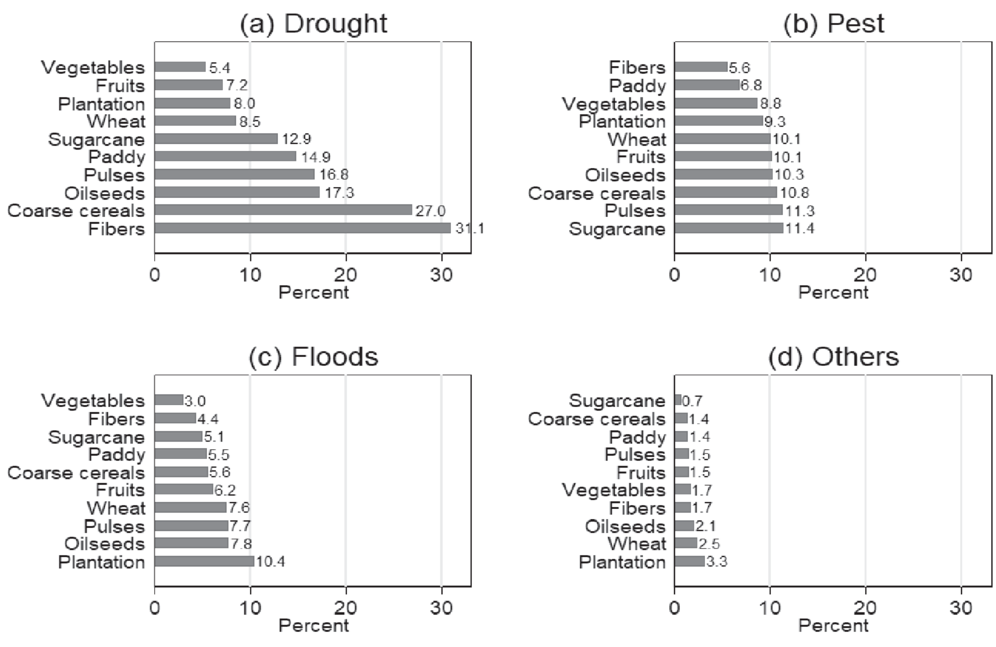

Figure 2. % farm households reporting crop loss in different crops by source of risk (%)

and maize) also face a comparable exposure to drought risk as cotton. Oilseeds, pulses, sugarcane and paddy rank next in that order. While, wheat, vegetables and fruits are relatively less exposed to droughts.

The significant variation in crops' exposure to droughts can be explained by several factors such as spatial differences in agro-climatic conditions (e.g., rainfall, temperature and soils) in which crops are grown, their capacity to tolerate moisture stress (i.e., their genetic potential), and use of adaptation measures (e.g., irrigation and stress-tolerant seeds). For example, cotton, coarse cereals, pulses and oilseeds are mostly grown in low rainfall arid and semi-arid regions that also have limited water for irrigation — only 17-34% of the area under their cultivation is irrigated (GoI 2016). About 40% of the paddy area is also rainfed, but it is confined to high-rainfall humid regions. Fruits, vegetables and wheat, on the other hand, are cultivated under irrigated conditions. Note, irrigation is one of the best adaptations against droughts (Birthal et al. 2015a).

As in the case of droughts, crops also differ in their exposure level to floods but the inter-crop variation in their exposure is not as high. Oilseeds, pulses, wheat and fruits have relatively higher but comparable exposure to flood risk — only 6 to 8% of the farm households cultivating these crops have reported loss in crops due to floods. On the other hand, vegetables, cotton, sugarcane, paddy and coarse cereals have a lower exposure to flood risk.

Also, there is little variation in farmers' responses to exposure to pest risk — 9 to 11% of the farmers, except those engaged in cultivation of cotton and paddy, have reported damage to crops due to insect-pests and diseases. Paddy and cotton are less exposed to pest risk. Cotton is supposed to be highly prone to pest risk, but the extensive use of Bt cotton seeds (that provide resistance to deadly pests like *Helicoverpa armigera)* has made it less vulnerable to pest risk.

Further, we assess crop loss by source of risk (Table 1). First, let's look at the extent of the total farm output lost on account of all types of production risks. On

Table 1. Returns, and loss in different crops by source of risk (Rs/ha)

Crop	Gross returns	Loss				
		Droughts	Pests	Floods	Others	Total
Fruits	232046	10653	5475	8445	2838	27410
	(31759)	(5169)	(1654)	(3448)	(1714)	(9370)
Sugarcane	148678	9357	5139	5391	436	20323
	(8957)	(3333)	(1040)	(3340)	(170)	(4766)
Plantation	134194	4469	4923	4612	2189	16193
	(9375)	(1092)	(1130)	(910)	(623)	(1864)
Vegetables	97535	3763	4403	1121	759	10046
	(5240)	(1259)	(1393)	(299)	(190)	(1926)
Cotton	52963	11698	1279	1332	470	14779
	(2385)	(1242)	(300)	(294)	(152)	(1247)
Paddy	49465	2831	970	1001	225	5027
	(3457)	(255)	(121)	(130)	(38)	(307)
Oilseeds	45391	4016	2137	1374	489	8015
	(2876)	(372)	(255)	(177)	(106)	(459)
Wheat	44677	1206	1397	1247	418	4268
	(1081)	(123)	(183)	(286)	(108)	(351)
Pulses	43880	3786	2705	1590	271	8352
	(5662)	(419)	(609)	(294)	(56)	(800)
Coarse cereals	24834	4268	1504	945	180	6897
	(841)	(303)	(273)	(203)	(40)	(436)
Total	59510	3875	2239	1607	492	8213
	(2068)	(261)	(256)	(169)	(57)	(492)

Figures in parentheses are standard errors.

average, production risks could reduce the potential[1] farm output or returns by Rs 8213 per hectare or 12.1%. And as expected, the droughts comprise the main cause of loss, sharing 47% of the total loss. Floods account for one-fifth of the total loss, and insect-pests about 27%. This pecking order of causes of loss in farm output is in line with the one reported in Ramaswami et al. (2003) and Cole et al. (2013).

Nonetheless, there is considerable variation in riskiness and returns across crops. Fruits, vegetables, sugarcane and plantations are at a greater risk, but these are also more remunerative to cultivate compared to other crops. These crops, however, differ in their vulnerability to different risks — fruits suffer more from droughts and floods; vegetables from insect-pests and droughts; and sugarcane from droughts. The loss in plantation crops is almost equally distributed among droughts, floods and insect-pests. Cotton, although, generates reasonably high returns, but it is also highly vulnerable to drought risk. Staple food crops, i.e., wheat and paddy, comparatively face low risk but also less remunerative. Causes of risk in these crops, however, differ — wheat experiences almost an equal loss on account of droughts, floods and pests; and the droughts comprise the main source of loss in paddy production. Compared to wheat and rice, the coarse cereals are at a greater risk, especially of droughts, and these are also the least remunerative to cultivate. Oilseeds and pulses generate comparable returns and also face comparable risk. These findings reveal that the crops that generate higher returns are also more vulnerable to production risks. In other words, these provide us an early indication of the possibility of trade-off between risk and returns in farmers' choice of crops.

We look at this issue further and estimate a simple nonparametric association between returns and output lost at farm-level for the sub-sample of farm households who had reported loss in a crop due to one or the other natural hazard (figure 3). At lower level of farm returns, the loss is also low (and almost constant), but after a threshold, both the loss and returns start moving in tandem, turning the relationship highly positive.

3 Empirical method

A farm household's exposure to risk can be modelled as:

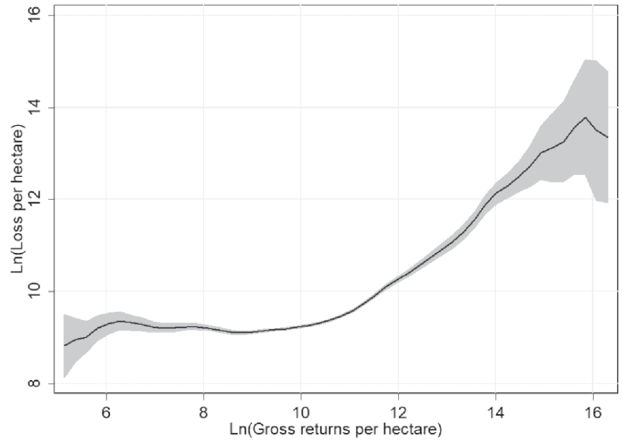

Figure 3. Non-parametric association between risk and returns

$$y_{civs} = \sum_{c} \theta^{c} Crop_{ivs}^{c} + \alpha_i^1 + \alpha_v^2 + \mu_s + \varepsilon_{civs} \qquad \ldots(1)$$

where, the dependent variable y represents a household's vulnerability to risk, in terms of its exposure to risk— it takes a value of 1 for those who suffered a loss in crop output and zero for others or the quantum of output lost per unit of land. The variable *Crop* with superscript c represents dummies for crops cultivated by a household in a particular season, and θ captures differential risk exposure of a crop in comparison to the base crop, which is the omitted category in the model.

Eq.(1) presents a general model of risk, where we have included three types of fixed effects: (i) the growing season dummy, denoted by μ_s, (ii) the village fixed effects, denoted by α_v^2, and (iii) the household fixed effects, denoted by α_i^1, so as to know their relative importance in explaining variation in households' or crops' exposure or vulnerability to risk. The crops grown and their exposure to different risks are generally seasonal; hence in all the specifications we retain the dummy for the growing season as a control for seasonality in cultivation of crops and also their level of exposure to risk. Subsequently, we add village fixed effects to control for the spatial differences in agro-climatic conditions (rainfall, temperature, irrigation and soil type), infrastructure, markets and institutions, that can potentially influence crops' exposure and vulnerability to risk. The riskiness of crops can also be influenced by several household-specific, observed and unobserved factors, such as land size, labor availability,

[1]Potential output equals actual output plus loss

financial status, education and skills; hence, we estimate Eq.(1) including household fixed effects.

Eq.(1) provides estimates of exposure or vulnerability of individual crops to different production risks. However, to understand the relationship between risk and returns in the choice of crop portfolio (at farm level) we specify the following model.

$$y_{civs} = \rho_{civs} + X_{civs} + \varepsilon_{civs} \quad \ldots(2)$$

where, the dependent variable y is the crop-specific loss per hectare for household i in village v during season s. r is the crop- and household-specific returns per hectare. The vector X contains household-specific controls like the dummies for causes of loss and growing seasons, and the village and household fixed effects. The coefficient of interest is ρ that captures the relationship between risk and returns or the trade-off between risk and returns in farmers' crop portfolios. Our hypothesis is that the riskiness and returns in farmers' crop portfolios are positively correlated, i.e., $\rho > 0$.

We estimate different specifications of Eq.(2), adding subsequently the higher levels of fixed effects to check the robustness of the coefficient, , that captures trade-off between risk and returns.

4 Econometric results

4.1 Exposure to risks

Estimates of Eq.(1) for exposure of a crop to the overall risk (with a binary dependent variable; 1 that has suffered loss, zero for others) are presented in table 2. Paddy is the base crop in our model; hence the regression coefficients on other crops are to be interpreted in relation to that on paddy.

Table 2. Regression estimates for exposure of crops to overall risk

Crop	With season fixed effects	With season and village fixed effects	With season and household fixed effects
Wheat	0.047***	-0.053***	-0.050***
	(0.011)	(0.009)	(0.010)
Coarse cereals	0.155***	-0.014*	-0.016
	(0.012)	(0.008)	(0.010)
Pulses	0.067***	-0.054***	-0.054***
	(0.011)	(0.008)	(0.010)
Oilseeds	0.063***	-0.057***	-0.049***
	(0.011)	(0.008)	(0.011)
Cotton	0.143***	0.028***	0.025*
	(0.017)	(0.010)	(0.013)
Sugarcane	-0.008	-0.038***	-0.033*
	(0.017)	(0.014)	(0.017)
Vegetables	-0.102***	-0.087***	-0.084***
	(0.010)	(0.007)	(0.009)
Fruits	-0.020	-0.094***	-0.076***
	(0.016)	(0.012)	(0.015)
Plantations	-0.006	-0.064***	-0.056***
	(0.015)	(0.010)	(0.013)
Base category: Paddy	0.287***	0.341***	0.338***
	(0.007)	(0.005)	(0.006)
Season dummy	Yes	Yes	Yes
Village fixed effects	No	Yes	No
Household fixed effects	No	No	Yes
Number of observations	101874	101874	101874
Adjusted R^2	0.030	0.426	0.469

Figures in parentheses are standard errors. ***,** and * indicate significance at 1, 5 and 10% respectively.

The growing season does not explain any variation in crops' exposure to risk — the adjusted R^2 is extremely small (0.03). In other words, the crops, irrespective of the differences in their growing seasons, are prone to one or the other type of production risk, and these vary in their level of exposure. The regression coefficients on crops indicate that relative to paddy, the coarse cereals, cotton, pulses, oilseeds and wheat are more exposed to production risks, while the high-value crops (except vegetables) are relatively less exposed to risks. The risk exposure of other crops is comparable to that of paddy.

With inclusion of the village fixed effects in the basic equation, the adjusted R^2 improves significantly to 0.43 (col. 3 of table 2). The coefficients on wheat, coarse cereals, pulses and oilseeds that were positive in the basic equation, have now turned negative and significant. The coefficients on other crops retain their direction and turn out to be statistically significant. The coefficient of determination as well as regression coefficients on different crops show that spatial dimensions are important in explaining crops' exposure to production risks.

Do the household fixed effects explain more variation than the village fixed effects? Column 3 (table 2) shows results of Eq.(1) estimated including the household fixed effects. The adjusted R^2 increases to 0.47, suggesting that the household-specific effects explain more variation in crops' exposure to overall risk than do the village-specific effects. However, the regression coefficients on most crops remain pretty much similar in their direction, magnitude and significance. On the whole, these findings suggest that compared to paddy, most other crops (except cotton) have a lower exposure to production risks.

Now, let's look at the exposure level of different crops to different production risks. Our preferred specification is the one that includes household fixed effects along with growing season fixed effects. Table 3 presents the results. To know the relative importance of production risks we compare the regression

Table 3. Regression estimates for exposure of crops to individual risks

Crop	Droughts	Pests	Floods	Others
Wheat	-0.048***	0.005	-0.012*	0.006*
	(0.008)	(0.007)	(0.006)	(0.004)
Coarse cereals	-0.034***	0.023***	-0.004	-0.000
	(0.007)	(0.007)	(0.006)	(0.003)
Pulses	-0.061***	0.014**	-0.004	-0.003
	(0.007)	(0.007)	(0.005)	(0.003)
Oilseeds	-0.062***	0.025***	-0.011*	-0.000
	(0.008)	(0.007)	(0.007)	(0.003)
Cotton	-0.004	0.028***	0.003	-0.001
	(0.010)	(0.008)	(0.007)	(0.004)
Sugarcane	-0.059***	0.034***	-0.013*	0.005
	(0.011)	(0.012)	(0.008)	(0.004)
Vegetables	-0.071***	0.004	-0.017***	0.001
	(0.007)	(0.007)	(0.005)	(0.003)
Fruits	-0.077***	-0.019*	0.017*	0.003
	(0.010)	(0.011)	(0.010)	(0.005)
Plantation	-0.060***	-0.027***	0.017**	0.015***
	(0.007)	(0.009)	(0.008)	(0.005)
Base category: Paddy	0.186***	0.080***	0.056***	0.014***
	(0.004)	(0.004)	(0.003)	(0.002)
Season dummy	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes
Number of observations	102541	102541	102541	102541
Adjusted R^2	0.530	0.331	0.267	0.216

Figures in parentheses are standard errors. ***,** and * indicate significance at 1, 5 and 10% respectively.

coefficients on paddy across risk categories and find that droughts comprise the most important risk in Indian agriculture, followed by insect-pests and floods.

Cotton has almost a similar level of exposure to drought risk as paddy, but most other crops are relatively less exposed to drought risk. Fruits and plantation crops are more exposed to flood risk, while wheat and oilseeds have relatively a lower level of exposure. The exposure of other crops to flood risk is comparable to that of paddy. Fruits and plantation crops are less prone to pest risk, while others (except wheat) are not.

4.2 Vulnerability to risks

The estimates presented in tables 2 and 3 indicate the extent of proneness of crops to different risks, but not the damages caused by these, which may differ on account of several factors such as differences in intensity of risk, crops' capacity to tolerate risk and measures taken to manage risk. To know the intensity of damage due to different production risks, we estimate Eq.(1) with crop loss as dependent variable. As for risk exposure specification, we estimate three specifications of the loss equation by including season dummy, village fixed effects and household fixed effects. Results are presented in table 4. Again the adjusted R^2 is the highest for the specification estimated with household fixed effects, which confirms a greater role of household characteristics in explaining variation in crops' vulnerability to risk.

The regression coefficients on crops provide us the estimates of loss relative to the loss in paddy. The estimated loss is significantly higher for fruits, followed by sugarcane, plantation crops, cotton and vegetables. This is expected, as these crops generate more returns

Table 4. OLS estimates of crop loss due to overall risk

Crop	With season fixed effects	With season and village fixed effects	With season and household fixed effects
Wheat	488.26	-1343.22	-1506.63
	(749.33)	(1119.89)	(955.61)
Coarse cereals	1822.81***	-3049.72***	-2922.37***
	(441.83)	(637.56)	(748.91)
Pulses	3792.97***	1058.21	1403.10
	(915.69)	(1210.11)	(1323.52)
Oilseeds	3960.35***	940.57	1092.32
	(677.75)	(892.77)	(932.64)
Cotton	9683.98***	3779.59***	4090.18***
	(928.39)	(917.85)	(1066.42)
Sugarcane	10186.07***	9089.45***	9020.87***
	(1269.18)	(1303.71)	(1498.09)
Vegetables	3858.11***	3283.26***	2596.92**
	(871.63)	(871.93)	(1148.62)
Fruits	15806.31***	10414.40***	10681.07***
	(2754.92)	(2635.61)	(2908.65)
Plantations	9432.72***	9230.38***	8801.25***
	(1345.72)	(1766.13)	(2088.03)
Base category: Paddy	4663.72***	6484.46***	6510.64***
	(422.61)	(556.58)	(638.15)
Season dummy	Yes	Yes	Yes
Village fixed effects	No	Yes	No
Household fixed effects	No	No	Yes
Observations	102504	102504	102504
Adjusted R^2	0.00	0.06	0.10

Figures in parentheses are standard errors. ***,** and * indicate significance at 1, 5 and 10% respectively.

per unit of land as compared to paddy and other crops. The loss in case of wheat, pulses and oilseeds is comparable to that of paddy. It is only the coarse cereals that are comparatively less vulnerable, but these are also the least remunerative to cultivate.

Further, we estimate the loss equation for each source of risk. There is considerable variation in crops' vulnerability to different risks (table 5). Compared to paddy, the fruits, cotton and sugarcane suffer more from droughts, while the coarse cereals and wheat suffer less. For other crops, the loss is comparable to that for paddy. The loss due to floods is higher in the case of fruits, sugarcane, cotton and plantation crops. Pest-induced loss is also higher in sugarcane and plantation crops.

4.3 Trade-off between risk and returns

The evidence presented so far clearly reveals the differences in crops' vulnerability to different types of production risks, and a possible trade-off between risk and returns in farmers' choice of crops. To statistically establish the relationship between riskiness and returns of crop portfolios chosen we estimate Eq.(2) where the loss in farm output is regressed on farm returns. We also include dummies for crop seasons and causes of loss, village fixed effects and household fixed effects in this equation. Results are presented in table 6. Columns 2 to 4 show the estimates for the overall sample. The coefficient on returns in column (2) is positive and highly significant, and it remains so even when the equation is estimated including the village (col.3) and the household (col.4) fixed effects. This lends support to our hypothesis that riskiness and returns in a crop portfolio are positively correlated.

In column 5 of table 6 we present results estimated for the sub-sample of farm households who had reported loss in crop outputs due to one or the other natural

Table 5. OLS estimates of crop loss by source of risk

	Droughts	Pests	Floods	Others
Wheat	-947.03**	-221.68	-301.73	-36.19
	(464.67)	(664.39)	(495.68)	(202.96)
Coarse cereals	-1917.32***	-847.70	-151.39	-5.96
	(417.00)	(526.90)	(244.52)	(167.03)
Pulses	-379.91	1448.67	293.08	41.27
	(611.04)	(1092.89)	(364.04)	(212.49)
Oilseeds	-148.60	708.26	100.08	432.57**
	(669.91)	(517.78)	(348.70)	(203.57)
Cotton	3053.57***	91.32	620.19**	325.10
	(806.33)	(637.26)	(288.27)	(210.84)
Sugarcane	2689.54***	4239.79***	1310.39**	781.14**
	(840.63)	(1000.73)	(662.65)	(344.96)
Vegetables	342.05	1185.97	542.27	526.62***
	(565.61)	(910.19)	(397.52)	(174.43)
Fruits	4775.16**	-214.27	4608.61***	1511.57**
	(2079.91)	(1570.52)	(1385.91)	(671.13)
Plantations	2025.70	1938.82**	3150.76***	1685.97***
	(1512.94)	(763.26)	(1076.41)	(637.59)
Base category: Paddy	3665.65***	1719.37***	1036.75***	88.86
	(299.90)	(468.33)	(192.47)	(143.84)
Season dummy	Yes	Yes	Yes	Yes
Household fixed effects	Yes	Yes	Yes	Yes
Observations	102504	102504	102504	102504
Adjusted R^2	0.06	0.02	0.22	-0.04

Figures in parentheses are standard errors. ***,** and * indicate significance at 1, 5 and 10% respectively.

Table 6. Regression estimates of the relationship between crop loss and returns

	(2)	(3)	(4)	(5)	(6)
Log(return)	0.091***	0.079***	0.078***	0.310***	-0.538*
	(0.006)	(0.006)	(0.008)	(0.024)	(0.310)
Log (return squared)					0.043***
					(0.015)
Dummy for cause of loss	Yes	Yes	Yes	Yes	Yes
Dummy for crop season	Yes	Yes	Yes	Yes	Yes
Village fixed effects	No	Yes	No	No	No
Household fixed effects	No	No	Yes	Yes	Yes
No. of observations	100391	100391	100391	28375	28375
Adjusted R^2	0.979	0.983	0.984	0.569	0.574

Figures in parentheses are standard errors. ***,** and * indicate significance at 1, 5 and 10%, respectively.

hazard. The relationship between riskiness and returns (col. 2 to 4) does not undergo a significant change. The regression coefficient on farm returns remains positive and significant, but turns out significantly larger. This confirms that riskiness of a crop portfolio increases with increase in its returns. From the nonparametric association between loss and returns we had observed that loss is low at low levels of returns, but after a threshold the relationship turns out highly positive. Hence, we estimate the equation including squared term of returns, and the results are shown in column 6. The regression coefficient on returns is negative but weakly significant, but it is positive and highly significant on the squared term of returns, suggesting that there is a trade-off between risk and returns in farmers' choice of crops.

We use the regression coefficients reported in column 6 to predict the trade-off between risk and returns in farmers' choice of crops (figure 4). As expected, the curve is almost flat or marginally negative at low levels of returns, but it rises steeply after a threshold level of returns. This confirms that there is a trade-off between risk and returns in farmers' choice of crops; risk-averse farmers cultivate crops that generate less but stable returns, while the farmers capable of bearing the cost of risk, *ex post*, cultivate more high-retrun, high-risk crops.

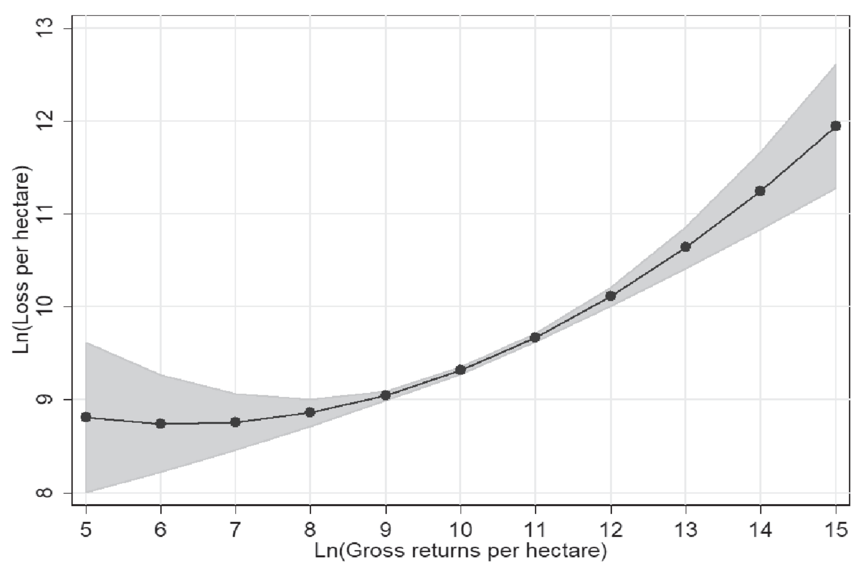

Figure 4. Simulated relationship between risk and returns

5 Discussion

A number of studies have highlighted the crop diversification as an adaptation strategy against climatic shocks, especially droughts in developing countries where markets for credit and risk products are either absent or underdeveloped (see, Dercon 1996). Walker and Jodha (1982) find multiple cropping as common adaptation strategy in low-rainfall semi-arid regions of India. Gadgil et al. (1988) report that in case of low soil moisture, farmers cultivate less area, but allocate more of it to the short-duration, less water-consuming crops. Farmers also substitute crops (Walker & Ryan 1990), follow inter-cropping (Birthal et al. 2000) and use pest-resistant seeds to avoid manage due to insect-pests and diseases. In flood-prone areas, farmers often grow crops and their varieties that can withstand sub-mergence conditions and they also follow inter-temporal diversification to cope with risk *ex post*, i.e., they allocate more area to post-rainy season crops that can grow well on the residual moisture (Goyari 2005; Mandal 2014; Dar et al. 2013). From a study in Tanzania, Dercon (1996) have clearly shown that there is a trade-off between risk and returns in farmers' choice of crops; the risk-averse farmers cultivating low-risk, low-return crops primarily to secure a stable livelihood. Further, it is also shown that low-risk, low-return crop portfolios do not allow farm households escape poverty trap.

In a recent study, Birthal and Hazrana (2019) have ascertained econometrically the importance of crop diversification in improving resilience of agriculture to deficit rainfall and excess temperature. They find adaptation benefits of diversification more apparent against severe shocks and in the long-run. In a wider context of effect of diversification on poverty, Birthal et al. (2015b) found that diversification toward high-return crops contributes to poverty reduction, but the resource-poor farmers are constrained to diversify because of the high production risks and fixed costs associated with diversification. Similarly, Khanal and Mishra (2017) argue that in the short-run crop diversification can be an important means of avoiding risk, but adjustments in the cropping systems to climatic risks through alternative crop portfolio choices might not provide maximum profits because of the fixed cost associated with adaptation to climatic risks. Nonetheless, they argue that farmers' access to off-farm income allows them to choose high-return, high-risk crop portfolios.

Our findings clearly show that there is a trade-off between risk and returns in farmers' choice of crops. The risk-averse farmers forego benefits of growing more remunerative crops in favor of low-return, low-risk crops in order to obtain a sustainable stream of income and consumption. On the contrary, the farmers who are willing to take risk choose high-return, high-risk crop portfolios. Rosenzweig and Binswanger (1993) and Khanal and Mishra (2017) have reported returns and riskiness of crop portfolios positively correlated with wealth or landholding size.

In India, cultivation of high-return, high-risk crops (i.e., fruits, vegetables, spices, plantation crops and sugarcane) is limited to about 10% of the gross cropped area despite that the returns these significantly outweigh the loss due to natural hazards. The probable reasons for this could be that: (i) farmers, especially smallholders, are more concerned about their household food security, which they ensure by allocating more area to low-risk, low-returns staple crops like paddy and wheat, (ii) high-value crops are more prone to market risks that discourage farmers to diversify toward these crops, (iii) some of the high-value crops, e.g. fruits, plantations and sugarcane, also require more of start-up capital, while the resource-poor farmers have limited capita and also access to institutional credit, and (iv) there are fixed costs associated with cultivation of perennial high-value crops, that means there is a need for a minimum efficient scale for profit optimization.

6 Conclusions and implications

This paper has examined exposure and vulnerability of crops to production risks such as droughts, floods and pests, and subsequently the trade-off between risk and returns in farmers' choice of crop portfolios. Findings indicate that at any point of time, about one-third of the farm households are exposed to production risks and suffer a loss of over 12% in their potential farm output. Drought with a share of 47% in the total loss comprise the main production risk, followed by insect-pests (27%) and floods (20%).

There is considerable variation in crops' exposure and vulnerability to drought risk, but not as much to flood and pest risks. In general, cereal crops have low risk and also low returns. Crops like fruits, vegetables, plantations and cotton are remunerative but these are also more prone to risks. In other words, the riskiness and returns in a crop portfolio are positively correlated or there exists a trade-off between risk and returns in farmers' choice of crops.

Indian agriculture is dominated by small landholders — over two-third of the farm households cultivate landholdings of less or equal to one hectare, which is barely sufficient to generate returns for a decent livelihood. Given this, our findings have a few important policy implications. High-return, high-risk crops require more start-up capital, while smallholder farmers lack access to institutional credit to investment in such crops. Besides the higher fixed costs of production, smallholder farmers also face higher fixed marketing and transaction costs because of small marketed surplus. The agricultural policy should, therefore, emphasize on providing farmers an easy access to credit, markets and institutions that help them reduce fixed costs associated with diversification toward high-value crops.

A majority of smallholder farmers undertake cultivation of low-risk, low-return staple food crops because of their poor access to insurance and alternative income and consumption security mechanisms that potentially influence their risk behaviour in their decisions on choice of crop portfolio. The performance of crop insurance in India, despite being subsidized, has been dismal; hardly 5% of the farm households, mostly the large farm households, avail crop insurance (Aditya et al. 2018). There could be several reasons for low uptake of crop insurance, that need to be investigated.

Access to alternative income opportunities eases liquidity constraint to the adoption of improved technologies, use of inputs and investment in productive assets and human capital. Unfortunately, farmers lack access to income opportunities outside agriculture. Their mean per capita income hardly exceeds one-fifth of the national per capita income. Although, 40% of their income comes from non-farm sources but mostly from the low-paid works (Birthal et al. 2017). The implication is that if the investment constraints to diversification are to be eased, there is a need for broad-based development of rural nonfarm sector.

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