Anomaly in Decision Making Under Risk: Violation of Stochastic Dominance Among Farmers in Gujarat, India

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ABSTRACT

Our study investigates farmers' decision making under risk by eliciting their willingness to pay (WTP) for hypothetical risky income distributions. To inquire whether farmers behave differently when gambles are framed as yield risk or price risk, we present these income distributions as those with constant price and variable yield to a set of farmers and those with constant yield and variable price to another set of farmers. We find that a significant number of farmers violate stochastic dominance, an assumption central to the validity of rational decision making. We also inquire whether such behaviour is related to their self-reported risk attitudes. We find that farmers who perceive themselves as risk takers are more likely to violate stochastic dominance than those who perceive themselves as risk avoiders. We explore reasons for such behaviour and posit conditions under which configural weight theories of decision making could explain such behaviour.

Keywords: Decisions under risk, experiments, stochastic dominance, India

JEL Codes: D81, D01, D03

1 INTRODUCTION

Agriculture is characterised by exposure to a multitude of risks in the context of natural, institutional, and regulatory environments. Farmers in developing countries tend to be conservative in their resource allocation decisions (Binswanger and Rosenzweig 1986; Alderman and Paxson 1992; Rosenzweig and Binswanger 1993) and allocate their resources to safe, low-risk, low-return activities (Jodha 1978; Walker and Jodha 1986; Townsend 1994; Jalan and Ravallion 2001). Also, in general, risk aversion and adoption of innovations are found to be inversely related (Feder 1980; Feder et al. 1985; Foster and Rosenzweig 2010). Therefore, it is of vital importance to understand how farmers in the developing world respond to risks and how they make decisions under risk.

The literature on agricultural decision making has paid considerable attention to the role of risk, uncertainty, and risk attitudes in agricultural decision making (Heady 1952; Anderson et al. 1977, 1992; Just and Pope 1978 1979 2003; Chavas and Holt 1996; Pope and Just 1998).[1] Virtually all economic inquiries into the role of risk and uncertainty in agricultural decision making assume that most farmers are 'risk-averse', but only a few studies have empirically validated this assumption.

Our paper contributes to this strand of literature by inquiring the attitudes towards risk of farmers from two *taluka*s in the Indian state of Gujarat. Previous such studies could be categorized into three types (1) studies that estimate risk attitudes based on the actual cropping decision of farmers (Moscardi and de Janvry 1977; Antle 1987); (2) studies that use farmers' self-reported attitudes towards risks; and (3) studies that use experiments based on farmers' choices among a set of hypothetical (or sometimes real) risky lotteries to estimate risk attitudes (Dillon and Scandizzo 1978; Binswanger 1980, 1981; Lybbert and Just 2007; Lybbert and Barrett 2007; Just and Lybbert 2012; Liu 2013; Maertens et al. 2014). Our study follows the second and third line of inquiry in understanding farmers' risk attitudes and their decisions under risk. We design experiments to analyse their behaviour towards risky incomes. We also test if this behaviour is associated with their self-reported risk attitudes.

We use a stochastic dominance-based approach to pursue our investigation. There are two notions of stochastic dominance—first order stochastic dominance and second order stochastic dominance. The first order stochastic dominance property states that as long as the utility function is weakly increasing, a risky lottery will be preferred to another if for any

[1] For a deeper understanding of how risk and uncertainty influence farmers' adoption decisions, a fundamental distinction between risk and uncertainty should be understood: risk entails the knowledge of the probabilities (subjective or objective) of different outcomes while uncertainty implies ignorance about such probabilities.

[2] See, for instance, Moscardi and de Janvry (1977); Binswanger and Ruttan (1978); Binswanger (1980, 1981); Dillon and Scandizzo (1978); Newbery and Stiglitz (1981); Antle (1987); Finkelshtain and Chalfant (1991); Ramaswami (1992). See Pratt (1964); Rothschild and Stiglitz (1970); Sandmo (1971); and Pratt and Zeckhauser (1989) for a detailed analysis of risk aversion and its role in decision making.

outcome x, it gives as high a probability as the other lottery for receiving at least x and for some x, it gives a higher probability of receiving at least x. In this context, the first order stochastic dominance property is considered the probabilistic analogue of the 'more is better' attitude (Machina 2004). Our study imposes conditions of first and second order stochastic dominance and sets up a null hypothesis of farmers' preferences conforming to first order stochastic dominance.

If farmers adhere to first order stochastic dominance (FOSD, henceforth), their risk attitudes could be elicited based on their adherence to or violations of second order stochastic dominance (SOSD, henceforth). According to SOSD property, a risk-averse agent with a weakly increasing utility function will prefer lottery 'x' to lottery 'y' as long as 'x' is more predictable (less variance) than 'y' and has at least the same mean. So, if utility is weakly increasing, we could infer violation of SOSD as evidence of risk-seeking behaviour. As we have also mentioned previously, anybody with a weakly increasing utility would not violate FOSD. So, if FOSD is not violated, we could elicit farmers' risk attitudes based on adherence to or violation of SOSD. But, evidence from the experimental outcomes reveals violations of FOSD. Subsequently, we explore the potential reasons for these violations. We also investigate the relation between farmers' self-reported attitudes towards risks and patterns of FOSD violations which provides some interesting findings.

An important aspect of designing these experiments the assumption of 'source of risk' to respondent farmers. Most often, farmers' risk is assumed to arise from variability in incomes or yields, but apart from yield, output price variations also form an integral part of a risk for the farmers (Newbery and Stiglitz 1981; Walker and Ryan 1990; Kurosaki 1998; Harwood et al. 1999; Hardaker et al. 2004). Although both price and yield risk ultimately affect farmers' final income, the magnitude of these risks and the interactions between these two vary across farmers and regions (Mehra 1981; Hazell 1982, 1983; Ranganathan and Gaurav 2013). Moreover, the formal and informal mechanisms used by farmers to deal with these two risks are different. While yield insurance, crop diversification, intercropping, and mixed cropping are measures taken by farmers to deal primarily with yield risk, trading in commodity futures and options and storage are some of the measures that deal largely with management of price risk. The formal institutions to tackle these risks might also be at differential stages of development, given the level of financial development of the economy. This suggests that farmers might respond differently to income risk from price and yield variations. In this study, we design experiments to evaluate if such is the case. We are not aware of any studies that have tested this aspect.

The paper is structured as follows. Section 2 details the experiment design. Section 3 provides the survey details and sample characteristics. Section 4 presents the data and the main results. Section 5 lists the major conclusions and discusses some policy implications.

2 EXPERIMENT DESIGN

In our experiments, we asked the farmers to value hypothetical seed bags with risky incomes. The risky incomes associated with the seed bags were presented either as those with yield risk (constant price, variable yield) or as those with price risk (constant yield and variable price). The income distributions were described by the probabilities of different income outcomes. By varying the probabilities of the income outcomes and eliciting farmers' WTP for these distributions, we assess farmers' decision making behaviour under risk.

All farmers who participated in the experiment were asked about their willingness to pay (WTP) for four seed bags. As we wanted to understand the decision making process of farmers in a realistic scenario, we used a 'context-specific' experiment and described the income distributions using seed bags (Lybbert 2006; Maertens et al. 2014). The participants were told that each of the four seed bags is associated with three possible risky incomes (INR 18000, INR 27000 and INR 36000; INR stands for Indian rupees) with different probabilities.[3] The mean and variance of these income distributions are presented in Table 1. Though hypothetical, these are not modest outcomes. If these incomes were to be realised on the average land size of farmers, the incomes would be in the range of 50–100 per cent of annual household income in the sample; levels that are considerable, based on our interactions with progressive farmers and local experts during the pre-testing phase of the surveys.

Table 1 Stochastic income distributions in the experiment

	Lottery Associated with Four Seed Bags			
Income	**L1**	**L2**	**L3**	**L4**
INR 18000	0.25	0.30	0.30	0.10
INR 27000	0.50	0.40	0.30	0.55
INR 36000	0.25	0.30	0.40	0.35
Expected value (INR)	27000	27000	27900	29250
Riance of distribution	40500000	48600000	55890000	31387500
Standard deviation of distribution	6,364	6,971	7,476	5,602

Note: L1, L2, L3, L4 denote the lotteries associated with the four seed bags.
INR is Indian Rupees.

Letting L1 to L4 denote lotteries represent four different distributions (arising out of four different seed bags), we can see that L1 and L2 have the same expected returns (mean), but L2 has a higher variance (risk) than L1[4]. Between L3 and L4, the mean of L4 is higher than L3 but its variability (riskiness) is lower than L3. The distribution L4 first order stochastically

[3] 1 GBP = 102.78 INR as on 3 August 2014.

[4] The distributions L2 could be seen as mean-preserving spread of L1 (with an increasing risk) in the sense of Rothschild and Stiglitz (1970, 1971).

dominates (FOSDs) the distributions L1 and L2, that is, any rational decision maker with a monotonic utility function would prefer L4 to L1 and L2. Similarly, L3 first order stochastically dominates (FOSDs) L2. Also, the distribution L1 second order stochastically dominates (SOSDs) distribution L2, i.e. any agent with a monotonic, concave utility function would prefer L1 over L2. Similarly, L4 second order stochastically dominates (SOSDs) L3. Rational economic behaviour under risk requires economic agents to adhere to conditions imposed by FOSD. If farmers adhere to rationality (adhere to conditions imposed by FOSD in our case), then violation of SOSD would imply risk-seeking behaviour. On the other hand, violations of FOSD would mean that it would not be appropriate to assume a weakly increasing utility function, a basic tenet of rational economic behaviour. So, if farmers violate FOSD, such violation cannot be automatically taken as evidence of risk-seeking behaviour.

Additionally, to find out if farmers behave differentially when lotteries are being framed as yield or price risk, we presented income distributions of seed bags as a fixed price but variable yield (uncertain yield) distributions to one set of farmers and as a fixed yield but variable price distributions to other set of farmers. The experiments were randomised among farmers: that is, randomly assigned to two sets of farmers with similar socioeconomic characteristics. The WTP for income distributions with a fixed price but variable yield was elicited for one set of farmers whereas WTP for income distributions with a fixed yield but a variable price was elicited among the other set of farmers. Tables 2a and Table 2b detail the distributions provided to two sets of farmers.

Table 2a Constant price and variable yield distributions

Constant Price = INR 4500/quintal				
Yield	L1	L2	L3	L4
4 quintals/acre	0.25	0.30	0.30	0.10
6 quintals/acre	0.50	0.40	0.30	0.55
8 quintals/acre	0.25	0.30	0.40	0.35

Note:

1 quintal = 100 kilogram; 1 acre = 4046.86 square metre

The figures denote probability associated with each seed bag for different level of yield, given constant price.

Table 2b Constant yield and variable price distributions

Constant Yield = 6 quintals/acre				
Price	L1	L2	L3	L4
INR 3000/quintal	0.25	0.30	0.30	0.10
INR 4500/quintal	0.50	0.40	0.30	0.55
INR 6000/quintal	0.25	0.30	0.40	0.35

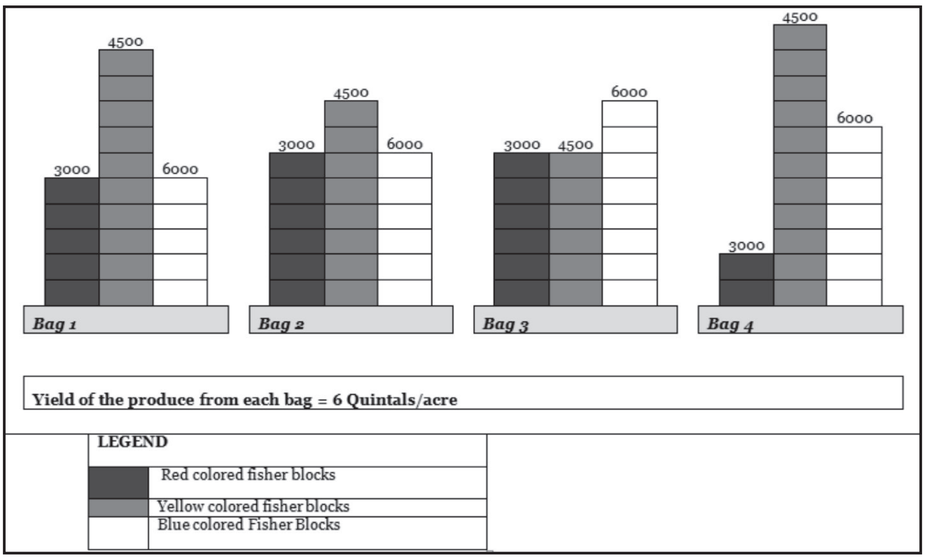
Note:

1 quintal = 100 kilogram

The figures denote probability associated with each seed bag for different levels of price, given constant yield.

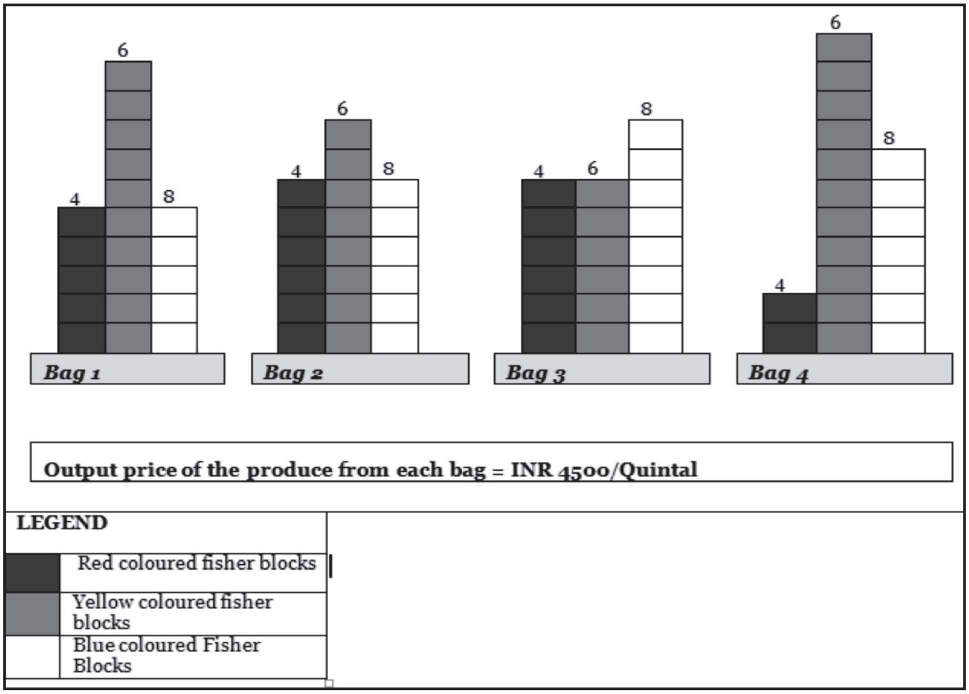
To arrive at prices and yields relevant to actual farmer experience, and hence their decision making, we used price and yield levels in accordance with crop-specific realisations usual for the region. The various stochastic price and yield distributions were presented to farmers using Fisher-Price building blocks to deal with their low literacy and numeracy (Lybbert et al. 2007; Maertens, Just, and Chari 2014). Fisher-Price building blocks of three colours—red (for worst outcome), yellow (for medium outcome), and blue—(for best outcome) were used for denoting yield and price distributions. Each block was representative of a 5 per cent probability of obtaining the corresponding outcome. For example, to denote the first yield distribution shown in Table 2a, 5 red blocks were stacked together vertically, which denoted a 25 per cent chance (probability of 0.25) of getting the worst yield (4 quintals/acre in this case). Besides these, 10 yellow blocks and 5 blue blocks were stacked to denote a 50 per cent chance of obtaining a medium outcome (6 quintals/acre) and 25 per cent chance of obtaining the best outcome (8 quintals/acre). A coloured printout of the stacking arrangement was made and provided as a part of the questionnaire to the investigators. Figures 1 and 2 represent the distributions presented to the two sets of farmers.

Figure 1 Representation of Fisher Block structures presented to a set of farmers (stable yield and stochastic price)



We have used an open-ended approach to elicit farmers' WTP for seed bags with the aforementioned income distributions. This method has been argued to be associated with certain issues such as 'coherent arbitrariness', which results from anchoring biases (Ariely, Loewenstein, and Prelec 2003). However, some studies rule out such biases; for example, in their re-examination of the effects of anchoring manipulation, Alevy, Landry, and List (2006) found weak anchoring bias, and Fudenberg, Levine and Maniadis (2012) found no anchoring bias. Moreover, since we had asked farmers to value seed bags and not any arbitrary income distribution, we believe the 'anchoring effects' might be low as the transactions are concerned with familiar and primarily private use values (Alevy, Landry, and List 2006).

Figure 2 Representation of Fisher Block structures presented to a set of farmers (stable price and stochastic yield)



3. **FIELD SURVEY DESIGN AND SAMPLE CHARACTERISTICS**

We study a random sample of 320 farmers from two agro-ecological zones of the state of Gujarat in western India; 160 farmers were presented with risky incomes arising out of stable yield, variable price, and the other 160 farmers were presented with risky incomes arising from stable price and variable yields. The experiments were conducted during the period June-July 2011 as a part of a larger survey that included 800 farmers in two *taluka*s (each a different agro-ecological zone) of the Indian state of Gujarat. We focused on paddy farmers in eight villages of Khambhat taluka in Anand district (totally 400; 50 from each village) and cotton farmers in eight villages of Khambha taluka in Amreli district (totally 400; 50 from each village). Figure 3 shows a map of Gujarat and our study regions. The villages were selected such that to have substantial socio-economic heterogeneity but to be more or less representative of the other villages in the district.

Figure 3 Map of the Indian state of Gujarat indicating study districts

Source: India Meteorology Department (www.imd.gov.in)

Note: The solid dots indicate the approximate location of our study talukas: Khambhat in Anand district and Khambha in Amreli district.

For the purpose of experiments, we assigned farmers randomly to the first and second set of experiments. This resulted in a random sample of 160 farmers (80 for set 1 and 80 for set 2) from each taluka (20 from each village). Therefore, a total of 320 farmers (160 from each taluka; 80 for set 1 and 80 for set 2) were randomly selected for experiments. Eventually, the responses of 153 farmers from Khambha taluka and 160 farmers from Khambhat taluka were consistent, and we confine our analysis to this set of 313 farmers.

2.1 Sample Characteristics

The characteristics of the two sets of farmers (set of farmers who were presented with seed bags with yield risk and the set who were presented with seeds bags with price risk) in our sample are summarised in Table 3.

Table 3 Sample characteristics of farmers subjected to different experiments

Characteristic	All farmers	Set 1	Set 2	Difference
Age (years)	45.07 (8.73)	45.01 (8.75)	45.12 (8.74)	-0.11
Household head's years of schooling	7.23 (3.23)	7.58 (3.04)	6.91 (3.38)	0.67
Number of members in the household	4.54 (1.13)	4.50 (1.09)	4.57 (1.17)	-0.07
Operated land (acre)	3.97 (2.38)	3.91 (2.64)	4.02 (2.11)	-0.11
Percentage of operated land irrigated (%)	99.55 (5.80)	99.34 (8.08)	99.75 (1.92)	-0.41
Agricultural income as a percentage of total income (%)	84.17 (34.94)	84.46 (34.80)	83.89 (35.18)	0.57
Total annual income (INR)	144178 (109253)	137771 (81934)	150267 (129985)	12496
N	313	153	160	

Note: First row – means; figures in parenthesis are standard deviations. Difference is the difference between means of Set 1 and Set 2. None of the differences are statistically insignificant at the conventional levels (based on t-test for comparison of means).

As a test of randomisation, it is important to note that none of the differences in means of the observed socio-economic variables across two sets are statistically significant (based on the t-test for mean comparison).

On an average, participants are 45 years old and had completed around seven years of schooling (at the time of survey). In terms of household demographics, the average household size is 4.54. The average size of the cultivated land is 3.97 acres. Almost all of the land is irrigated, with the average percentage being 99.6 per cent. In terms of livelihoods the dependency on agriculture for total income is around 85 per cent. The average annual household income of the farmers in the sample is around INR 145000.

4 DATA AND RESULTS

Table 4 presents the summary of willingness to pay (WTP) for the four distributions L1, L2, L3, and L4 (mean and standard deviations of these four distributions are INR 27000, INR 6364; INR 27000, INR 6971; INR 27900, INR 7476; and INR 29250, INR 5602; respectively, where the first element represents expected returns (mean) and the second element represents riskiness (standard deviation)).

Table 4 Summary of WTP data among two sets of farmers

	All Farmers	Set 1	Set 2	Difference
WTP for L1 distribution	751 (143)	751 (145)	752 (141)	-2
WTP for L2 distribution	783 (141)	779 (143)	786 (139)	-7
WTP for L3 distribution	806 (153)	814 (167)	799 (139)	15
WTP for L4 distribution	832 (163)	838 (175)	827 (150)	11
First Order Stochastic Dominance (FOSD) Relationships				
Number (Percentage) of farmers who pay more for L4 than L1	191 (60.8%)	92 (60.1%)	99 (61.5%)	-1.4%
Number (Percentage) of farmers who pay more for L4 than L2	176 (56.1%)	87 (56.9%)	89 (55.3%)	1.6%
Number (Percentage) of farmers who pay more for L3 than L2	183 (58.3%)	90 (58.8%)	93 (57.8%)	1.0%
Second Order Stochastic Dominance (SOSD) Relationships				
Number(Percentage) of farmers who pay more for L1 than L2	61 (19.4%)	33 (21.6%)	28 (17.4%)	4.2%
Number (Percentage) of farmers who pay more for L4 than L3	170 (54.1%)	77 (50.3%)	92 (57.8%)	-7.5%
N		313	153	160

Note: Figures in parentheses indicate standard deviation. Difference is the difference between means of Set 1 and Set 2. None of the differences (Either the differences in mean in the case of WTP or the difference in proportions of farmers adhering to conditions imposed by first order and second order stochastic dominance) between set 1 and set 2 farmers are statistically significant.

The difference in average WTP among set 1 and set 2 farmers is lowest (INR 2) in case of L1 while it is highest (INR 15) in case of L3. None of the differences is statistically significant. We observe that average WTP for L4 is highest while that for L1 is lowest. Among L4, L3 and L2, we find that average WTP for L4 is higher than L2 and that of L3 is higher than that for L2. These are in line with the conditions imposed by FOSD. Similarly, the average WTP for L4 is greater that L3 in accordance with conditions imposed by SOSD. However, average WTP of L2 is greater than L1, which violates SOSD.

A disaggregated analysis of the WTP apart from summary statistics provides some important insights. As mentioned previously, adherence to FOSD would have meant that farmers pay more to L4 than to L1 and L2 and also more to L3 than to L2. But, we find that 39 per cent farmers in the sample value L1 above L4; 44 per cent of farmers value L2 above L4; and 42 per cent value L2 above L3. Similarly, conditions imposed by SOSD would mean farmers value L1 more than L2 and L4 more than L3. Here again, 81 per cent farmers value L2 over L1 and about 46 per cent farmers value L3 over L4. This clearly indicates that a large number of farmers are violating FOSD and SOSD.

In Table 4, we also test whether the proportion of farmers adhering to conditions imposed by stochastic dominance differs when income risk is posed as price risk and when it is posed as a yield risk. The difference in percentage of farmers adhering to stochastic dominance is least in the test of adherence to WTP for L3> WTP for L2 (1 per cent) and highest in test of adherence to WTP for L4> WTP for L3 (7.5 per cent). But, none of the differences are statistically significant (based on z-test of difference between two proportions).

Table 5 Violations of first order stochastic dominance (FOSD)

	All Farmers Rs.	Set 1	Set 2	Difference
Number of farmers who adhere to all three conditions imposed by FOSD	138 (43.9)	69 (45.0)	69 (42.9)	-2.1%
Number of farmers who violate all three conditions imposed by FOSD	71 (22.6)	36 (23.5)	35 (21.7)	1.8%
Number of farmers who adheres to only one condition imposed by FOSD : WTP for L4 > WTP for L1 and violates the remaining two (WTP for L4 > WTP for L2 and WTP for L3> WTP for L2)	34 (10.8)	16 (10.5)	18 (11.2)	-0.7%
Number of farmers who adheres to only one condition imposed by FOSD : WTP for L3 > WTP for L2 and violates the remaining two (WTP for L4 > WTP for L1 and WTP for	29 (9.2)	12 (7.8)	17 (10.6)	-2.8%
Number of farmers who violate only one condition imposed by FOSD : WTP for L3 > WTP for L2 and adhere to the remaining two (WTP for L4 > WTP for L1 and WTP for L4 > WTP for L2)	15 (4.8)	5 (3.3)	10 (6.2)	-2.9%
Number of farmers who violate only one condition imposed by FOSD : WTP for L4 > WTP for L1 and adhere to the remaining two (WTP for L4 > WTP for L2 and WTP for L3 > WTP for L2)	12 (3.8)	7 (4.6)	5 (3.1)	1.5%
Number of farmers who adheres to only one condition imposed by FOSD : WTP for L4 > WTP for L2 and violates the remaining two (WTP for L4 > WTP for L1 and WTP for L3> WTP for L2)	11 (3.5)	6 (3.9)	5 (3.1)	0.8%
Number of farmers who violate only one condition imposed by FOSD : WTP for L4 > WTP for L2 and adhere to the remaining two (WTP for L4 > WTP for L1 and WTP for L3 > WTP for L2)	4 (1.3)	2 (1.3)	1 (1.2)	0.1%
N	313	153	160	

Note: Difference is the difference between means of Set 1 and Set 2. None of the differences in proportions of farmers following any particular adherence and violation pattern between set 1 and set 2 farmers are statistically significant. Figures reported in parentheses are percentages.

4.1 Patterns of Stochastic Dominance Violations

Given that we observe violations in conditions imposed by stochastic dominance, we further inquire into the patterns of such violations. Tables 5 and 6 provide the patterns of stochastic dominance violation among our sample of farmers. We first focus on the violation of FOSD (Table 5). Only 44 per cent of farmers adhere to all conditions imposed by FOSD. The remaining 56 per cent seem to violate at least one condition imposed by FOSD. We observe that around 23 per cent of the farmers violate all the three conditions imposed by FOSD. Also, 24 per cent of farmers violate two out of three conditions imposed by FOSD, and the remaining 9 per cent of farmers violate only one condition imposed by FOSD. There is no clear pattern that emerges on which of the three conditions is more easily violated by farmers. The only reasonable inference we could draw from the observation is that when farmers violate one condition, they tend to violate at least one more condition imposed by FOSD. The Table also indicates the differences in proportion of farmers following a particular pattern of adherence/violation of conditions imposed by FOSD when they are posed with price risk and when posed with yield risk. We find that none of the differences based on z-test for difference between two proportions is statistically significant.

Table 6 provides the summary of patterns of SOSD violations among the farmers. Unlike FOSD violations, there is a much clearer pattern of adherence/violation observed here. More farmers (82 per cent) violate the SOSD WTP for L1 > WTP for L2 than the SOSD - WTP for L4 > WTP for L3 (45 per cent). There is only a small percentage (5 per cent) of farmers who adhere to both the conditions imposed by SOSD. Around 32 per cent of farmers violate both the conditions imposed by SOSD, while 63 per cent violate one of the conditions imposed by SOSD. The table also indicates the differences in proportion of farmers following a particular pattern of adherence/violation of SOSD when they are posed as price risk and when posed as yield risk. We find that none of the differences based on z-test for difference between two proportions is statistically significant.

Table 6 Violations of second order stochastic dominance (SOSD)

Farmers	All	Set 1	Set 2	Difference/ (overall)
Number of farmers who adheres to SOSD : WTP for L4> WTP for L3 but violates the SOSD: WTP for L1> WTP for L2	154 (49.0)	68 (44.4)	86 (53.4)	-9.0%
Number of farmers who violate both the conditions imposed by SOSD	99 (31.5)	52 (33.9)	47 (29.2)	4.7%
Number of farmers who adheres to SOSD : WTP for L1 > WTP for L2 but violate the SOSD: WTP for L4 > WTP for L3	45 (14.3)	24 (15.7)	21 (13.0)	2.7%
Number of farmers who adhere to both the conditions imposed by SOSD	16 (5.1)	9 (5.9)	6 (4.3)	1.6%
N	313	153	160	

Note: Difference is the difference between means of Set 1 and Set 2.None of the differences in proportions of farmers following any particular adherence and violation pattern between set 1 and set 2 farmers are statistically significant. Figures reported in parentheses are percentages.

4.2 What Makes Farmers Violate Stochastic Dominance?

We have observed that a substantial number of farmers have violated both first and second order stochastic dominance. About 39 per cent, 44 per cent, and 42 per cent of farmers violate the conditions imposed by FOSD; that of WTP of L4 should be more than that of L1, WTP of L4 should be more than that of L2, and WTP of L3 should be more than that of L2, respectively. We also observe that 81 per cent and 19 per cent of the farmers violate the conditions imposed by SOSD; that of WTP of L1 should be greater than that of L2 and WTP of L4 should be greater than that of L3, respectively. The violations of FOSD conditions mean that violations of SOSD cannot be used to elicit risk attitudes of farmers. So, to further inquire why farmers violate the FOSD conditions, we run probit regressions to identify the determinants of these violations. Table 7 presents the regression results.

Table 7 Probit regression results for violations of stochastic dominance

	Violation of FOSD Conditions		
Dependent Variable	Violated WTP for L4> WTP for L1	Violated WTP for L4> WTP for L2	Violated WTP for L3> WTP for L2
Presented with yield risk (=1 if risk presented as yield variability)	0.09 (0.03)	-0.11 (-0.04)	-0.20 (0.06)
Cotton farmer (=1 if cultivated cotton)	0.30 (0.10)	0.32* (0.12)	0.06 (0.02)
Age of household head	0.13 (0.04)	-0.01 (0.00)	0.02 (0.01)
Age of household head squared	-0.001 (0.00)	0.000 (0.00)	0.000 (0.00)
Household head's years of schooling	-0.05 (-0.01)	-0.01 (0.00)	0.07** (0.022)
Operated land (in acres)	-0.11** (-0.035)	0.01 (0.00)	-0.03 (-0.01)
Log (annual household income in)	0.58** (0.19)	0.38* (0.14)	0.39* (0.13)
Agricultural income as percentage of total income	-0.01*** (-0.003)	-0.003 (0.00)	-0.002 (0.00)
Self-perception of risk taking ability (with 1 indicating extreme risk avoidance and 10 indicating extreme risk taking)	0.43*** (0.14)	0.44*** (0.16)	0.46*** (0.15)
Intercept	-11.87***	-7.16***	-9.12***
Pseudo R-squared	0.3571	0.3543	0.3672

Note: *, **, *** denote statistical significance at 10%, 5%, and 1% level of significance respectively. Figures in brackets indicate the marginal effects of the independent variable on the probability of the dependent variable.

The dependent variable takes the value of '1' if the farmer violates any of the three FOSD conditions and '0' when the farmer adheres to them. We investigate the role of various farm and farmer characteristics in determining the probability of a farmer violating a particular FOSD.

From Table 7, we find that various factors play a key role in determining the violation of FOSD by farmers. Whether the income risk is presented as a yield or price risk does not seem to influence the violation of any of the conditions imposed by FOSD. Interestingly, the crop grown has a bearing on the probability of violation: being a cotton farmer (as against a paddy farmer) increases the probability of violating one of the conditions significantly.

Farmer's age does not play a role in influencing the chance of violation of FOSD, while the household head's years of schooling has a positive association with the violation of one of the conditions. The probability of violation of one of the conditions imposed by FOSD goes up by 2.2 per cent with an additional year of schooling. This result is surprising, and rules out to some extent cognitive inability (assuming a positive relationship between cognitive ability and education) as a reason for the violation of stochastic dominance. Household assets play a role in farmers' preference for stability. The amount of land operated negatively affects the violation of one of the conditions. The probability of violation of the particular condition falls by 3.5 per cent for an increase in land operated by an acre, suggesting that larger farmers are less likely to violate the condition. The probability of violation of one of the conditions decreases also with the share of agriculture income in household income.

Two other factors seem to influence the chance of violation of all the conditions imposed by FOSD: (1) total farm household income and (2) farmers' perceived risk-taking ability. The marginal effects of total household annual income on the probability of violation of the three conditions are 19 per cent, 14 per cent, and 13 per cent, respectively. Interestingly, farmers' self-perceived risk-taking ability seems to positively influence the violation of all the conditions. With a marginal increase in farmers' perceived risk-taking ability, the probability of violation of the three conditions increases by 14 per cent, 16 per cent, and 15 per cent.

Three possible explanations for the FOSD violations can be put forth. First, the observed patterns of violation could be related to cognitive distortions (see Gaurav and Singh (2012), a study among farmers in the same region). However, as we find in one particular case (Column 3 of Table 7), the household head's education positively impacts the probability of violation of that condition, and, assuming that education and cognitive abilities are positively associated, a negative association between cognitive ability and violation of FOSD is unlikely. We also ran regressions with the ability of farmers to read and write Gujarati as regressors (regression results provided in Table 8), and found that the variables were either not significant or had positive coefficients in some cases. This implies that low cognitive ability of farmers cannot be taken as an explanation for FOSD violations.

Table 8 Probit regression results for violations of stochastic dominance with extra variables 'ability to read Gujarati' and ability to write Gujarati'

	Violation of FOSD Conditions		
Dependent Variable	Violated WTP for L4> WTP for L1	Violated WTP for L4> WTP for L2	Violated WTP for L3> WTP for L2
Presented with yield risk (=1 if risk presented as yield variability)	0.10 (0.03)	-0.11 (-0.04)	-0.21 (-0.07)
Cotton farmer (=1 if cultivated cotton)	0.31*	0.34*	0.05
	(0.10)	(0.12)	(0.02)
Age of household head	0.11	-0.04	0.02
	(0.04)	(-0.01)	(0.01)
Age of household head squared	0.00	(0.00)	0.00
	(0.00)	0.00	(0.00)
Household head's years of schooling	-0.05	-0.05	0.06
	(-0.02)	(-0.02)	(0.02)
Operated land (in acres)	-0.11**	0.01	-0.03
	(-0.03)	(0.003)	(-0.01)
Log (annual household income in)	0.59**	0.43*	0.40*
	(0.19)	(0.15)	(0.13)
Agricultural income as percentage of total income	-0.01***	0.00	0.00
	(-0.003)	(-0.001)	(0.15)
Self-perception of risk taking ability (with 1 indicating extreme risk avoidance and 10 indicating extreme risk taking)	0.43*** (0.14)	0.43*** (0.15)	0.47*** (0.15)
Ability to read Gujarati (=1 if the farmer is able to read a newspaper in Gujarati)	-0.65 (-0.24)	-0.18 (-0.07)	0.94 (0.22)
Ability to write Gujarati (=1 of the farmer is able to write his/her name in Gujarati)	0.91 (0.22)	1.18* (0.30)	-0.71 (-0.26)
Intercept	-11.81***	-7.65***	-9.49***
Pseudo R-squared	0.36	0.36	0.37

Note: *, **, *** denote statistical significance at 10%, 5%, and 1% level of significance respectively. Figures in brackets indicate the marginal effects of the independent variable on the probability of the dependent variable.

Second, farmers are involved in various activities apart from farming (diversified livelihoods), and also face various risks apart from price and yield risk in farming. This means that when they take decisions, they are concerned about a multitude of unmitigated 'background risks' and might correlate the presented risks negatively with other risks. For example, farmers might believe that to earn the highest income of INR 36000 per acre, they might have to put a high amount of labour in their farm, which would reduce their time allocated to more profitable opportunities. In one of the FOSD violation probit regression (Column 1 of Table 7), we do find that the variable 'share of agricultural income in total household income' has a negative influence on the probability of violation, substantiating our conjecture.

Table 9 Probit regression results for violations of stochastic dominance with extra variable 'Experienced shock of high input price in the last 3 years'

	Violation of FOSD Conditions		
Dependent Variable	Violated WTP for L4> WTP for L1	Violated WTP for L4> WTP for L2	Violated WTP for L3> WTP for L2
Presented with yield risk (=1 if risk presented as yield variability)	0.11 (0.03)	-0.08 (-0.03)	-0.19 (-0.06)
Cotton farmer (=1 if cultivated cotton)	0.33* (0.11)	0.39* (0.14)	0.07 (0.02)
Age of household head	0.12 (0.04)	-0.01 (-0.004)	0.02 (0.01)
Age of household head squared	0.00 (0.00)	0.00 (0.00)	0.00 0.00
Household head's years of schooling	-0.05 (-0.02)	-0.02 (-0.01)	0.07** (0.02)
Operated land (in acres)	-0.11** (-0.03)	0.01 (0.005)	-0.03 (0.01)
Log (annual household income in)	0.54** (0.17)	0.29 (0.10)	0.38* (0.12)
Agricultural income as percentage of total income	-0.01*** (-0.003)	-0.007*** (0.003)	-0.003 (0.00)
Self-perception of risk taking ability (with 1 indicating extreme risk avoidance and 10 indicating extreme risk taking)	0.40*** (0.13)	0.37*** (0.13)	0.45*** (0.15)
Experienced shock of high input price in the last 3 years	-0.38* (0.13)	0.73*** (0.26)	0.10 (0.03)
Intercept	-11.12***	-5.60**	-8.86***
Pseudo R-squared	0.36	-0.38	-0.37

Note: *, **, *** denote statistical significance at 10%, 5%, and 1% level of significance respectively. Figures in brackets indicate the marginal effects of the independent variable on the probability of the dependent variable

The final explanation is related to the manner in which farmers make decisions under risk and uncertainty. Their decisions might not adhere to explanations by Expected Utility Theory (EUT), Rank Dependent Theory, or Cumulative Prospect Theory, but they do adhere to explanations by descriptive or psychological theories called configural weight models (Birnbaum et al. 1992). For example, a special transfer of attention exchange (TAX) model

(Birnbaum 2005) could explain observed FOSD violation patterns of farmers under certain specific parameter values. For certain parameter values that indicate a high pessimism or high attention to particular parts of distributions, violations of stochastic dominance could occur. In our case of farmers focusing entirely on the probability of getting the lowest income (INR 18000) alone, FOSD violations could be explained. If the attention is focussed on probability of getting INR 18000 and INR 27000 alone, the violation of WTP of L3 greater than WTP of L2 could be explained. Also, when there is great pessimism, agents might tend to underplay the likely outcomes. We ran the above three probit regressions with one more independent variables: whether farmers faced input price shocks in the past three years (regression results provided in Table 9). We found this variable to be significant indicating that pessimism due to recent shock could have affected farmers' decision making. Appendix 2 provides illustration of how pessimism and high transfer of attention to certain distributions could cause violations in FOSD.

5 DISCUSSION AND CONCLUSIONS

How farmers in the developing world make decisions under risk has always been an issue of inquiry. Most studies have analysed farmer attitudes assuming that (1) the behaviour of farmers under risk could be explained by the expected utility theory and (2) income risk and yield risk are mostly synonymous to a farmer. Our paper finds that these assumptions might not always hold, and that the behaviour of farmers under risk needs to be investigated more.

In our experiments with farmers, we find that a significant number of farmers violate FOSD. Therefore, SOSD violations cannot be used to elicit farmers' attitudes to risk, and we proceed to inquire why farmers violate FOSD. An inquiry into the patterns of violations reveals that farmers who violate one of the three FOSD relations are more likely to violate other FOSD relations as well. Investigating the reasons for FOSD violations, we find that the household's crop choice, education of household head, land operated, and share of agricultural income in total household income play a significant role. Household's total income and the household head's perceived risk-taking ability has a positive impact on the violations of all three conditions imposed by FOSD. In analysing the reasons for violations, we were able to dismiss the relevance of cognitive ability as an explanation for FOSD violation. We believe there might be a role of background risk, pessimism, and transfer of attention to some income outcomes which could possibly explain the violations of FOSD. Future research needs to test these hypotheses more rigorously.

In summary, our paper raises some important questions pertinent to the farmers' risk attitudes and theories of their decision making under risk. The assumption of expected utility framework while measuring risk attitudes may not be right always and doing so without any appropriate background tests could provide with faulty interpretations about farmers' risk attitudes. We find that designating any of the well-known theory of decision making under risk (EU theory, RDU and CPT) a priori to measure risk attitudes may not be appropriate if it does not involve any tests of validity. We also find that in some cases (based on SOSD violations, the probit regression results are provided in Table 10), framing of income risk as a price or yield risk matters in farmers' behaviour under risk. This is critical, as farmer responses to innovations that affect the yield distributions might be quite different from market restructuring innovations that may alter the price distributions. It might not be safe to assume farmers would behave similar in both situations even if the resulting income distribution/risks are similar.

Table 10 Probit regression results for violations of second order stochastic dominance

	Violation of SOSD Conditions	
Dependent Variable	Violated WTP for L1> WTP for L2	Violated WTP for L4> WTP for L3
Presented with yield risk (=1 if risk presented as yield variability)	-0.24 (-0.07)	0.32* (0.12)
Cotton farmer (=1 if cultivated cotton)	0.05 (0.01)	0.86*** (0.07)
Age of household head	-0.12 (-0.03)	-0.01 (-0.003)
Age of household head squared	0.001 (0.00)	0.00 (0.00)
Household head's years of schooling	0.02 (0.01)	-0.003 (0.00)
Operated land (in acres)	0.11** (0.03)	-0.03 (0.01)
Log (annual household income in)	-0.44* (-0.12)	0.58** (0.22)
Agricultural income as percentage of total income	0.003 (0.00)	-0.002 (0.00)
Self-perception of risk taking ability (with 1 indicating extreme risk avoidance and 10 indicating extreme risk taking)	-0.28*** (-0.08)	0.33*** (0.13)
Intercept	9.60***	-9.02***
Pseudo R-squared	0.21	0.36

Note: *, **, *** denote statistical significance at 10%, 5%, and 1% level of significance respectively. Figures in brackets indicate the marginal effects of the independent variable on the probability of the dependent variable

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APPENDIX

APPENDIX 1 CHOICE QUESTION PRESENTED TO THE FARMER

As in any of your farm produce, there is always a chance of a good, bad and average price. We indicate four seed bags which would provide you a stable yield of 6 quintal per acre. But, the produce from this seed could be sold for different prices based on whether the quality is good, bad or average. We will show you in the blocks the chances of obtaining a bad, average and good quality output from the seed bag. You have to indicate how much you would pay for each of the bags.

Blue block indicates good price (INR 6000 / quintal) and the height indicates the chance of getting a good price, yellow block indicates average price (INR 4500 / quintal) and the height indicates the chance of getting a average price and the red block indicates bad price (INR 3000 / quintal) and the height indicates the chance of getting a bad price.

Interviewer check point: Please get the amount the respondent willing to pay by first probing in round figure (say 1200 or 1300). then ask him to the nearest 50 (say if the farmer says he is ready to pay anything less than 1100, ask him if he will pay less than 1050 or more than 1050, if he says more than 1050, then ask whether he will pay more than 1075 or less than 1075 and so on till you get a convincing answer. give considerable time for getting the answers to this question).

APPENDIX 2 ILLUSTRATIVE FOSD VIOLATION PATTERNS UNDER SPECIAL TAX MODEL

The special Transfer of Attention Exchange (TAX) model assumes that the utility of a gamble is the weighted average of the utilities of the consequences, where each probability-consequence branch is weighted by the product of a function of probability and a utility of the consequences of the branch. Certain weight is also transferred between different branches in a TAX model. In the special TAX model, Weight is transferred from branches leading to higher consequences to branches leading to lower consequences. The model could be mathematically described as follows:

$$G = (x, p; y, q; z, 1 - p - q)$$

$$U(G) = \frac{Au(x) + Bu(y) + Cu(z)}{A + B + C}$$

$$A = t(p) - \delta t(p)/4 - \delta t(p)/4$$

$$B = t(q) - \delta t(q)/4 + \delta t(p)/4$$

$$C = t(1 - p - q) + \delta t(p)/4 + \delta t(q)/4$$

Where x, y and z are the consequences;

U(G) is the utility of the gamble;

u() is the utility function of the consequence. In our example, we assume u(a) = α^{β}; $\beta > 0$

t() is the probability weighing function. In our example we assume t(b) = b^{γ}; > $\gamma < 1$ indicates optimism while $\gamma > 1$ indicates pessimism.

δ is the transfer of attention parameter. $\delta >= 0$.

We observe that three parameters β, γ and δ would eventually determine the preference between gambles of the farmer in our example. The following tables (Table A1 to Table A4) provide some of the parameter values for which we can observe the FOSD violation patterns as in our study.

Table A1 Some parameter values for which all three FOSD conditions are violated

γ	β	δ
1	0.8	3.4
1	0.8	3.6
1	0.8	3.8
1	0.8	4
1	1	3.4
1	1	3.6
1	1	3.8
1	1	4

Table A2 Some parameter values for which none of the three FOSD violations are violated

1	0.6	0
1	0.6	0.2
1	0.6	0.4
1	0.6	0.6
1	0.6	0.8
1	0.6	1
1	0.6	1.2
1	0.6	1.4
1	0.6	1.6
1	0.6	1.8

Table A3 Some parameter values for which only one of the three FOSD violations are violated

1.4	0.8	2
1.4	0.8	2.2
1.4	0.8	2.4
1.4	0.8	2.6
1.4	0.8	2.8
1.4	1	2
1.4	1	2.2
1.4	1	2.4
1.4	1	2.6
1.4	1	2.8

Table A4 Some parameter values for which two of the three FOSD violations are violated

3.2	1	2.6
3.4	0.8	2.6
3.4	1	2.6
3.6	0.6	2.6
3.6	0.8	2.6
3.6	1	2.6
3.8	0.6	2.6
3.8	0.8	2.6
3.8	1	2.6
4	0.6	2.6
4	0.8	2.6
4	1	2.6

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