'Sticky Rice': Variety Inertia in a Technologically Progressive State of India

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Abstract:

In this paper, we study an interesting case of variety inertia in an otherwise technologically progressive region of India. We examine the high adoption of Pusa 44, an environmentally unsustainable, old rice variety in Punjab, despite the availability of many newer improved varieties and the overall technological advancement of agriculture in the region. We use detailed household data on variety adoption and crop economics, collected from a primary survey conducted in 2017. We find that the 'stickiness' of Pusa 44, i.e. the resistance of rice farmers to adopt newer and more sustainable varieties, is explained by a lack of economic incentives. The private benefits obtained from higher yields of Pusa 44 compared to other varieties, far exceed its immediate costs, as the use of ground water resources is easy and inexpensive. Moreover, farmers perceive yield as the most important of variety traits, which further affects their choice in favour of Pusa 44. Policy intervention is important in this set up where the natural resource cost is not fully realized, and growing Pusa 44 results in negative externalities. We find some evidence that government intervention in the seed supply system can help promote the switch to newer, more sustainable rice varieties.

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Abstract

In this paper, we study an interesting case of variety inertia in an otherwise technologically progressive region of India. We examine the high adoption of Pusa 44, an environmentally unsustainable, old rice variety in Punjab, despite the availability of many newer improved varieties and the overall technological advancement of agriculture in the region. We use detailed household data on variety adoption and crop economics, collected from a primary survey conducted in 2017. We find that the 'stickiness' of Pusa 44, i.e. the resistance of rice farmers to adopt newer and more sustainable varieties, is explained by a lack of economic incentives. The private benefits obtained from higher yields of Pusa 44 compared to other varieties, far exceed its immediate costs, as the use of ground water resources is easy and inexpensive. Moreover, farmers perceive yield as the most important of variety traits, which further affects their choice in favour of Pusa 44. Policy intervention is important in this set up where the natural resource cost is not fully realized, and growing Pusa 44 results in negative externalities. We find some evidence that government intervention in the seed supply system can help in promoting the switch to newer, more sustainable rice varieties.

1.   Introduction

Technological change is important for agricultural growth in developing countries. There has been extensive research on the factors determining the adoption and diffusion of technology in agriculture. (Feder, Just and Zilberman, 1981; Feder and Slade, 1984; Rogers, 1995; De Janvry and Sadoulet, 2002; Foster and Rosenzweig, 2010) A subset of this literature empirically studies the adoption of improved seed varieties and their impact on farmers' productivity. (Becerril and Abdulai, 2010; Cunguara and Darnhofer, 2011; Shiferaw et al., 2014; Ghimire, Huang and Shrestha, 2015) Several different factors are found to affect the decision to adopt improved technologies and improved seed varieties, depending on the location and context of the study: knowledge and information, uncertainty and risk, credit constraints, price and profitability of the technology, and household characteristics like farm size and education. In many Indian states, the current varietal turnover is very slow. Farmers continue to grow low yielding varieties that were released decades ago, and are resistant to switching to newer varieties. (Krishna, Spielman and Veettil, 2016)

However, Punjab is known for its fast-moving adoption of technology and innovation. Punjab's agriculture sector is characterized by the high productivity of its farmers, with the majority using conservation agriculture machines, improved and high yielding seed varieties, chemical fertilizers, and modern irrigation technology. The Green Revolution started in this part of India, and it has shown tremendous growth in productivity and capacity to adopt new technology ever since. (Feder and O'Mara, 1981; Singh and Kohli, 1997; Johnson, Hazell and Gulati, 2003) Farmers in Punjab grow mainly two crops: rice in Kharif season (May – October) and wheat in the Rabi season (October – April). Within rice, there are basmati varieties and non-basmati varieties[1]. We find that the farmers are growing the latest and most advanced wheat and basmati varieties available. The average age of wheat varieties is only 4.5 years in our sample. But when it comes to non-basmati rice, the same farmers are choosing to grow Pusa 44, a long duration, water intensive variety which was not only released 23 years ago, but is also environmentally unsustainable. This technological backwardness is surprising considering the fast varietal turnover in wheat and basmati rice for the same farmers, and the overall progress of agriculture in Punjab. Nearly all the farmers own tubewells and electric pump sets to irrigate with ground water, and use advanced technology like laser land levellers in their fields. There is little research on the phenomenon of variety inertia in a region with overall technological

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[1] Basmati is a variety of long, slender-grained aromatic rice which is traditionally from the Indian subcontinent.

advancement, especially in the background of natural resource depletion. The aim of this paper is to understand the unique features of the Pusa 44 rice variety that make it popular but unsustainable, and to study what is driving its continued high adoption in Punjab.

Foltz, 2003 studies the pattern of diffusion of resource-conserving agriculture technology. He finds that reducing market imperfections in the pricing of natural resources so that the farmers pay the 'true' resource cost, can speed up the diffusion of resource-conserving technology, if there is no information or credit barrier. This is relevant in the case of Punjab, where the farmers neither lack information, nor are credit constrained. Instead, we find that the 'stickiness' of Pusa 44 i.e. the resistance to switch to more recent and more sustainable rice varieties is explained by a lack of incentives for the farmers. Pusa 44 has the advantage of higher yield over other varieties, even though it needs more water and other inputs like fertilizer and pesticide. Easily available ground water, coupled with the government's policy of supplying free electricity (see Hindustan Times, 2017), results in the wide adoption of this water intensive variety. The private benefits achieved from higher net returns on cultivating Pusa 44 far exceed the private costs of cultivation. In this set up, the farmers have little incentive to care about the social costs they incur. Moreover, contrary to what is common in the technology adoption literature, we find that growing Pusa 44 is not determined by farmer/household characteristics, credit constraints, or information sources. It is however influenced by the availability of water, by the source from which a farmer obtains seeds, and by geographical location. We also find that farmers perceive yield as the most important trait of a variety, which skews their choice in favour of Pusa 44. Higher yields provide farmers with larger marketable surplus and more grain for own consumption. However, increased yields at the cost of ground water depletion is unsustainable and there is a need to promote the use of newer, more sustainable rice varieties that have comparable yields to those of Pusa 44.

In the recent years, there has been a push from the Punjab Agriculture University to discourage the use of Pusa 44 as there are now newer rice varieties available to farmers in Punjab, that have shorter maturity periods and require lesser water. (The Tribune, 2017) Newer varieties like PR 121, PR 123, PR 124, PR 126, and PR 127 are positioned as replacements for Pusa 44. However, in our sample, apart from PR 121, which was released in 2013, we find that the adoption of these varieties in 2016-17 is negligible. Pusa 44 is still the most widely adopted rice variety, with 42% farmers growing it in 50% of the rice area. There are large parts of Punjab where Pusa 44 strongly dominates. We find that the region of central Punjab, namely the districts Barnala, Sangrur, Moga, Ludhiana and Muktsar, have falling ground water tables,

and highly unsustainable, high rates of Pusa 44 adoption. This is challenging for the state as the growing ground water depletion poses a threat to the sustainability of its current rice-wheat farming system. (Indian Express, 2013) The north-Indian region of Punjab and Haryana is called the 'food bowl' of India, and plays a vital role in sustaining food security in the country. The water and energy intensive rice-wheat system is becoming less profitable as these resources become increasingly scarce. There is an annual shortage of about 1.2 M ha metres of water in Punjab, that is being met primarily through ground water exploitation, as it is more reliable for farmers to use tubewells than other sources like rain or canals. (Hira, 2009; Chauhan et al., 2012) Replacing Pusa 44 with newly developed short duration rice varieties that require lesser water to grow, will also be crucial in managing the ground water problem in Punjab.

The rest of our paper is organized as follows. Section 2 describes our sampling strategy, data, and the features of Pusa 44. In section 3, we discuss summary statistics, and compare the characteristics of Pusa 44 farmers to other rice variety farmers. Section 4 presents our results from a linear probability model and Probit model, studying the drivers of Pusa 44 adoption. Section 5 concludes.

2.   Sampling Strategy and Data

To study the adoption of improved varieties and farm management practices, we conducted a primary survey of farmers in Punjab for the 2016-17 agricultural year. We selected 12 predominantly rice and wheat growing districts from Punjab namely: Amritsar, Barnala, Fatehgarh Sahib, Firozpur, Faridkot, Gurdaspur, Jalandhar, Ludhiana, Moga, Muktsar, Sangrur and Tarn Taran. These are mapped in **Figure 1** below. Within each district, we randomly sampled one or two blocks (sub-district administrative level) where rice-wheat systems predominate. We then randomly selected 5-6 villages from each district, making a total of 63 villages in our sample. In each village, we first conducted house listing to have a large sample of farm households, from which we randomly selected 20 households for the survey. Our final sample after data cleaning consists of total 1121 farm households. The survey covered detailed information on household characteristics, crop and variety adoption, crop economics, and use of conservation agriculture technology. A team of trained enumerators collected the information via ODK (Open Data Kit) software on tablets from April to July 2017. The cropping seasons covered are 2016-17 Rabi and Kharif (winter and summer cropping seasons).

From our data, we find that in Punjab, 72% farmers are rice growers, 89% are wheat growers and 43% are basmati rice growers. For our analysis in this paper, we consider only the non-

basmati rice growing farmers. So, we have a sample of 839 rice farmers. 384 of them are growing Pusa 44 and 485 are growing other rice varieties in 2016-17. We find that the main rice varieties grown in Punjab are Pusa 44, PR 114 and PR 121. Other rice varieties with very low rates of adoption are PR 111, PR 126, PR 122, PR 124, PR 127, PR 43, Hr varieties, Pili Pusa, Parmal PR, Sharbati and Pusa 50. These are all public varieties, released by the Indian Agriculture Research Institute (IARI) and the Punjab Agriculture University (PAU).

Figure 2 shows the distribution of rice area in Punjab by rice variety. Pusa 44 is the dominant variety, covering 50% of the total rice area in our sample. The other two main varieties, PR 114 and PR 121, have lower adoption areas of 12% each. The category 'PR Others' includes PR 126 (1%), PR 122 (2%), PR 124 (2%), PR 47 (3%), PR 43 (0.5%). 'Others' includes Hr varieties (1%), 666 (1%), Pili Pusa (1%), Parmal (4%), Sharbati (0.2%), and Pusa 50 (1%). (Percentage area of the variety out of total rice area is shown in parenthesis) We have clubbed these varieties into the two broad categories as the percentage of farmers growing each variety is lower than 2%, making the sample for individual varieties too small for separate analysis.

Figure 3 is a map of the percentage of rice area under Pusa 44 in each of the 12 sample districts. There is locational clustering of Pusa 44, with adoption concentrated mainly in central and south-central Punjab. This is the rice belt of Punjab. Moga, Barnala and Sangrur districts have the highest percentage of Pusa 44 area, followed by Ludhiana, Muktsar, Jalandhar and Faridkot. The rice area in the remaining districts is covered primarily by the other rice varieties. Only 3-4% of rice area is covered by Pusa 44 variety in the northern districts of Amritsar, Gurdaspur and Tarn Taran. From **Figure 4** we find the same pattern for percentage of Pusa 44 farmers within districts. The highest numbers are concentrated within central Punjab in Moga, Barnala, Sangrur and Ludhiana, where as high as 90% of rice farmers are cultivating Pusa 44 variety. These 4 districts can thus be considered as the 'target' districts in forming policy around the adoption of newer rice varieties.
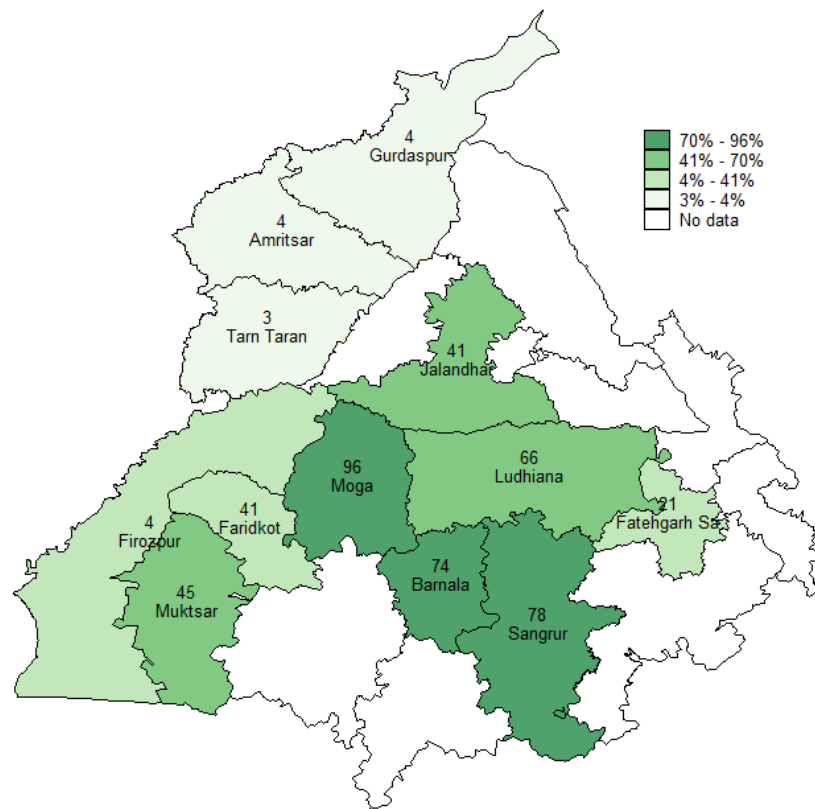
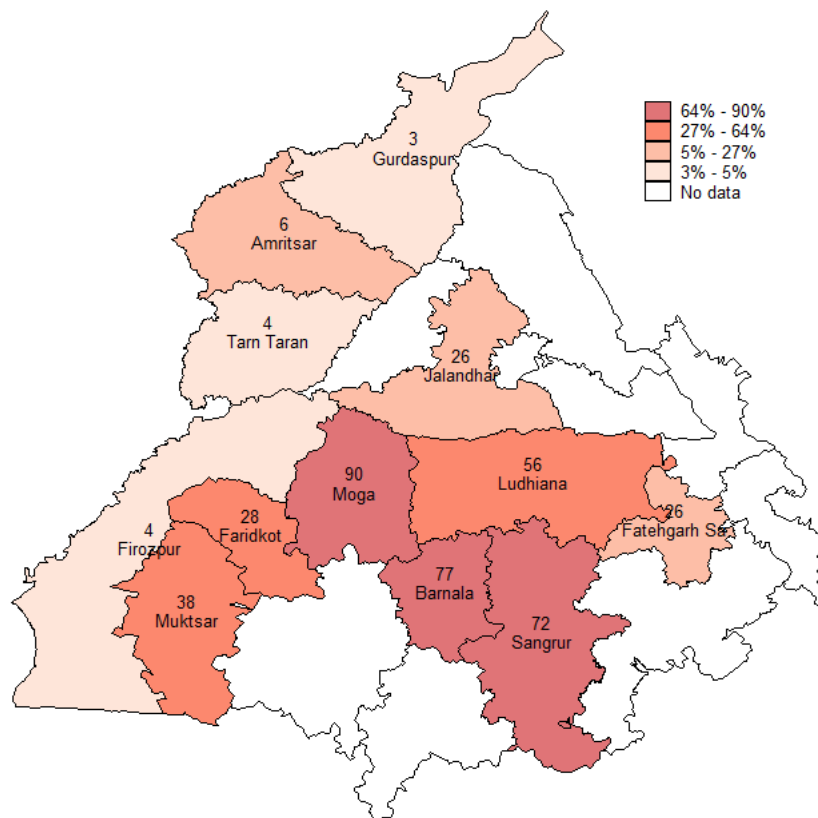**Figure 1: Sample Districts of Punjab: 12 major rice-wheat cultivating districts**

Figure 2: Rice Variety Area (% of total rice area from sample districts of Punjab)
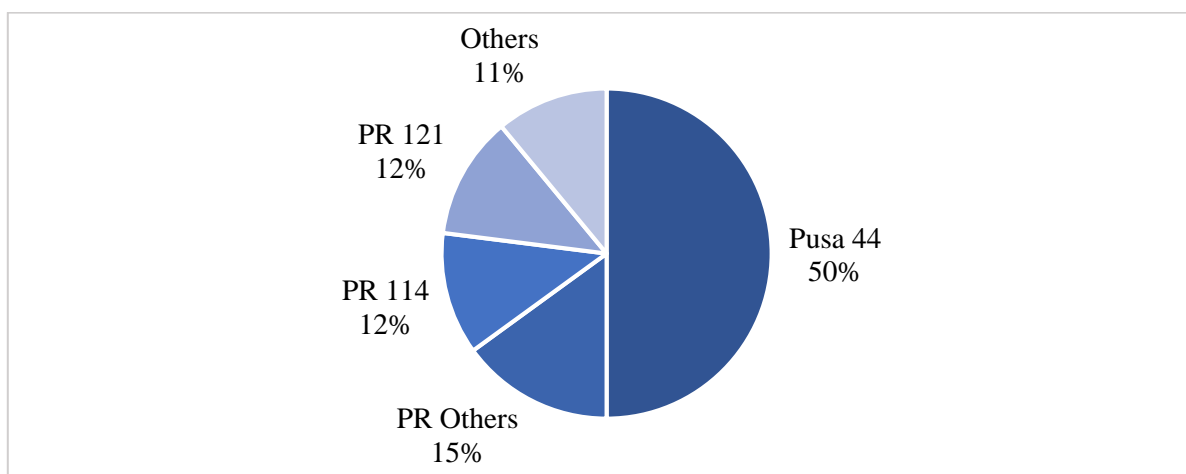
Figure 3: Percentage of rice area under Pusa 44 in sample districts of Punjab

Figure 4: Percentage of rice farmers growing Pusa 44 in sample districts of Punjab

We summarize the unique features of Pusa 44 compared to the other major rice varieties grown in Punjab in **Table 1**. Pusa 44 was released in 1994, making it the oldest variety still grown in Punjab. Many newer improved varieties have been released both by IARI and PAU, that have shorter maturity periods, high yields, and require lesser water and other inputs. A few examples are PR 123, PR 124, PR 126 and PR 127. From our data, we calculated the average maturity period of Pusa 44 to be 155 days. PR 114 and PR 121 have shorter maturity periods of 145 and 140 days each. This is shown in panel 1 of **Table 1**. Faster maturing varieties use lesser inputs overall, and allow sufficient time for field preparation before sowing the next crop. However, water is readily available to farmers in Punjab, with nearly every farmer owning a tubewell and electric pump set in our sample. This fact, combined with the state's policy of supplying free electricity, allows farmers to grow longer duration Pusa 44 variety, without suffering additional costs.

We find that Pusa 44 is more water intensive that other varieties. We show in panel 2 of **Table 1** that in the areas with high adoption of Pusa 44 (districts having more than 60% area under Pusa 44 cultivation), the water table is on average 101.16 feet. This is much deeper than the water table in low adoption areas, which is only 62.36 feet. The difference is highly significant and likely to be a result of high adoption of this water intensive variety. We also find that farmers in high adoption districts have larger pump sets for drawing water, again highlighting the possibility of further ground water exploitation. The average pump size in high adoption districts is 5.27 hp per hectare whereas in low adoption districts, farmers are using smaller pump sets of only 3.27 hp per hectare. The central part of Punjab is the primary rice belt and is extensively irrigated with pumped ground water. The overexploitation of ground water in central Punjab has been well documented in the literature. (Hira, 2009; Singh, 2011; Chauhan et al., 2012; Kaur and Vatta, 2015) Rice is already a water intensive crop, and the state has been trying to reduce its rice area and diversify to other crops. With the high percentage of Pusa 44 growers in central Punjab, the groundwater problem is likely to get worse. Pusa 44 is also known to be more prone to pests and diseases like bacterial blight, which is something we find in our data as well. As shown in panel 3 of **Table 1**, a significantly greater percentage of Pusa 44 farmers report having experienced pest attacks or diseases in the last 5 years, as compared to farmers growing other rice varieties. Their average expenditure on pesticides is also higher therefore. Rice varieties that require lesser pesticide are desirable as they have less harmful effects on soil fertility and allow the farmer to incur lower input costs.

However, in our sample, Pusa 44 farmers have significantly higher yields and higher net returns than farmers who are growing other rice varieties. Pusa 44 gives an average yield of 31.22 quintal per acre, which is 3 to 4 quintals higher than the average yields of PR 114 and PR 121. To calculate the cost of cultivation, we used information on cost of seeds, fertilizers, pesticide/insecticide, herbicide/weedicide, diesel, micro-nutrients, and cost of labour and machinery for sowing, transplanting, harvesting, and threshing. Cost of cultivation for the three varieties is similar but Pusa 44 has a slightly higher input cost compared to the other two. We use the value of minimum support price (MSP) for 'A' grade rice variety, which was Rs. 1,510 per quintal, to calculate the net returns for each farmer. In Punjab, rice is procured by the government at the MSP. As a result, farmers growing Pusa 44 and other rice varieties, get the same price for their produce in the market. We calculate that the average net return for Pusa 44 farmers is equal to 35,379 Rs. per acre. This is significantly greater than the net returns for farmers growing PR 114 and PR 121. Despite additional input costs and longer maturity period, farmers growing Pusa 44 enjoy much higher net returns due the higher yields. There is little consideration of the intensive water use, with the private benefits exceeding private costs. This table highlights the public good nature of rice variety adoption, with its negative externalities. Farmers gain from growing an environmentally harmful variety of rice because they experience private benefits from doing so. The switch to newer, short duration varieties with lower water requirement like PR 121 and the more recently released PR 126, is not happening because farmers are easily able to afford growing Pusa 44, and benefit from its higher yields.

Table 1: Features of Pusa 44

1. Old variety with long maturity period

Rice Variety	Release Year	Maturity Period
Pusa 44	1994	155 days
PR 114	2001	145 days
PR 121	2013	140 days

2. More water intensive than other varieties

Districts with	Water table depth in tubewells (in feet)	Pump size per hectare (in hp)
High adoption of Pusa 44 (>60% area)	101.16	5.27
Low adoption of Pusa 44 (<60% area)	62.36***	3.27***

3. Prone to pests and diseases: needs more pesticide

Rice Variety	Percentage of farmers reporting pest/disease	Average pesticide cost (Rs./acre)
Pusa 44	81%	2,300
PR 114	65%***	2,000***
PR 121	76%***	1,800***

4. High yield and net returns per acre

Rice Variety	Yield (quintal/acre)	Cost of cultivation (Rs./acre)	Net returns (Rs./acre)
Pusa 44	31.22	11,849	35,379
PR 114	28.35***	11,271*	31,543***
PR 121	27.46***	11,323**	30,672***

Note: For Panel 2, *, **, *** denotes that the difference in means between high adoption districts and low adoption districts is significant at 10%, 5% and 1% level of significance respectively. For Panel 3 and 4, *, **, *** denotes that the difference in means between the variety and Pusa 44 is significant at 10%, 5% and 1% level of significance respectively.

3. Comparing Pusa 44 adopters to farmers who adopt other rice varieties

We present the summary statistics from the main variables in our dataset in **Table 2**. Farmers are grouped into two categories: 'Pusa 44 adopters' and 'Other variety adopters'. 'Other variety adopters' includes farmers growing all other rice varieties in Punjab, apart from Pusa 44. We have 354 Pusa 44 adopters and 485 other variety adopters. Comparing the means of different sets of variables like farmer characteristics, source of seed purchase, source of information about variety, reasons for adoption, and production characteristics, we get an idea of how Pusa 44 adopters differ from those who grow other varieties.

In panel 1 of **Table 2**, we summarize the household characteristics. On average, Pusa 44 adopters are similar to other variety adopters based on farmer and household characteristics. From a simple t-test, the difference in means is statistically significant only for caste, crop loss and debt. Pusa 44 adopters are 46 years old on average, 99% of them are male, and 96% are from the general caste category. They have a family size of 6 members on average, and maximum farmers (29%) have a secondary school education. 97% of Pusa 44 adopters own land. The distribution of Pusa 44 farmers by size of land holdings is: 8% marginal, 19% small, 29% medium, and 44% large farmers. We categorize farmers as being marginal, small, medium or large based on the standard criteria in Indian agriculture economics. They are categorized as marginal farmers if total land is less than or equal to 1 hectare, small farmers if it is between 1 and 2 hectares, medium farmers if it is between 2 and 4 hectares, and large farmers if it is larger than 4 hectares. Note that majority of the farmers in Punjab are medium or large farmers. 98% of the Pusa 44 adopters have bank accounts and 68% have kisan credit cards. 94% report their household's primary occupation as agriculture. The means for household and farmer characteristics for 'Other variety adopters' is similar to those of Pusa 44 adopters. The differences in column 5 are insignificant, except for the differences in caste composition, crop loss and debt. Pusa 44 adopters are 3% more likely to be from the general caste category than other variety adopters. They are also 6% less likely to have experienced any crop loss in the

2016-17 agricultural year, and are 5% less likely to have any outstanding debt. These differences are significant, but small. Overall, it seems that household and farmer characteristics are similar across the two groups of farmers, and are thus unlikely to affect the decision to adopt Pusa 44 variety over other rice varieties.

To understand the seed supply side effect and the role of information networks, we asked farmers their source of seed purchase of the variety that they are growing, as well as their source of first information about this variety. From **Table 2**, panel 2, we find that maximum number of Pusa 44 adopters, i.e. 66%, purchase seeds from private distributers/companies, followed by 25% from local seed dealers in the village or block. These percentages are similar for other variety adopters, with 60% purchasing seeds from private and 29% from local seed dealers. A very small percent of farmers obtains seeds from government institutions or research centres in Punjab. 3% for the Pusa 44 group and 7% for the other variety group. For our overall sample, an average of 5.5% farmers in Punjab purchase seeds from the government. However, in column 5, we find a significant difference in the percentage of farmers who report purchasing their seeds from a government source. Pusa 44 adopters are 4% less likely to have purchased seeds from a government source. Since the government discourages the use of Pusa 44 and is trying to promote other newer varieties, farmers who obtain seeds from a government institution are more likely to purchase other variety seeds. This highlights the important role of government extension and support to farmers, that is needed to enable the switch to other rice varieties. Even though the government penetration in the seed supply market is low, it makes a significant difference to the variety choice of farmers.

We find no difference in means for the source of information about the varieties that the farmers adopt. This is shown in panel 3 of **Table 2**. We find that 37% of Pusa 44 adopters report relatives or other farmers as their main source of information. This is similar for other variety adopters. Relatives/other farmers is the most frequent source of information overall in our sample of farmers. The second most frequent source is village zamindar, followed by input dealers and print media. The category 'Others' under sources of information includes public and private extension, radio, tv, family (from past generations), and internet. Each of these have very low frequencies as reported sources of information. Thus, the information source is unlikely to be a factor explaining the choice of variety adopted by the farmers. Pusa 44 adopters and other variety adopters are equally likely to have obtained variety information from each of the different sources. Another thing to note from panel 3, is the low percentage of farmers reporting government or private extension as their source of seed variety information. It seems

that social networks like relatives and other farmers in the same village, are the major channels of information spread, rather than extension support. However, we cannot say that there is low extension, as we have not explicitly documented the access to extension, and the types of extension accessed. Here we had merely asked the source of first information about the variety.

We also asked each farmer his/her main reason for adopting a rice variety. The options included all possible variety traits such as grain yield, water requirement, drought resistance, pest resistance, chemical fertilizer requirement, reliability of buyers, selling price, earliness in maturity, good taste, good cooking quality, dry fodder yield, less labour requirement, and grain size. Moreover, if farmers reported a reason other than these, it was specified under an 'other reason' option. In panel 4 of **Table 2**, we have summarized the percentage of farmers who reported their main reason for variety adoption as grain yield, reliability of buyers, selling price and earliness in maturity. These were the 4 major reasons reported by farmers in the sample. We have clubbed the rest into an 'Other reasons' category, whose main components in the data are input traits like fertilizer requirement, labour requirement and water requirement. In panel 4, we see significant differences in means across the two groups. Grain yield is 10% more likely to be reported as the main reason for adoption for Pusa 44 farmers. This is no surprise, as we noted in **Table 1** that Pusa 44 has much higher yield than other rice varieties. Grain yield is more important for Pusa 44 farmers than all other variety traits. Further, there are no differences in percentage of farmers in the two groups reporting reliability of buyers or selling price as their main reasons for adoption. This is in line with the MSP procurement story discussed before. Moreover, earliness in maturity is 4% less likely to be a reason for adoption for Pusa 44 farmers. Since maturity periods of other varieties are shorter than Pusa 44 on average, farmers who choose to adopt varieties other than Pusa 44 are expected to give more importance to this feature. We also find that Pusa 44 farmers are 9% less likely to report 'Other reasons', namely input traits like fertilizer, labour and water requirement as their main reasons for adopting Pusa 44. Adoption of other varieties are more likely to be explained by these factors. This is also evident from **Table 1**, where we see that other rice varieties require lesser water and other inputs than Pusa 44.

In panel 5 of **Table 2**, we compare some of the important farm and production characteristics that we think may differ across the two groups of farmers. We find that Pusa 44 adopters and other variety adopters largely differ in these characteristics. We start by looking at the area under cultivation of the rice variety and find that Pusa 44 farmers grow the variety in a larger area on average. Pusa 44 area is 9.41 acre whereas other variety area its 6.23 acre; 3.18 acre

lower than the Pusa 44 area. This difference is large and significant. This is likely because Pusa 44 farmers are growing only one rice variety, and only very few of them additionally grow basmati rice. A greater percentage of other variety adopters are also growing basmati rice; hence their area of non-basmati rice cultivation is lower[2].

Further, we find that 64% of Pusa 44 adopters use laser land leveller, 3% use zero tillage and 99% own tubewells. These are not significantly different across the two groups. Other variety adopters are also equally likely to use laser land leveller, zero tillage and own tubewells. However, for the other variables measuring water use, we find that Pusa 44 adopters differ on average from other variety adopters. They have water tables in their tubewells of 94 feet, which is 22.67 feet deeper than those of other variety adopters. We calculated the decline in water level over the past 10 years using recall data from farmers wherein they reported the water level in their tubewells 10 years prior to 2016-17. We see that the decline in water level (water gap) is significantly larger for Pusa 44 adopters as compared to other variety adopters. They are also 6% more likely to own electric pumps to draw water, and have larger pump sets of approximately 5 hp per hectare, as compared to 3.68 hp per hectare of other variety adopters. These differences are statistically very significant (1% level of significance). Pusa 44 farmers have a greater capacity to draw water from deeper ground water tables. The deeper water tables are also likely to be a cause of growing the more water intensive variety. However, we cannot attach a causal interpretation to the results in **Table 2** as they compare only the means across the two groups, and do not control for other factors that may influence adoption. Panel 5 also reiterates the differences in yields and net returns for the two groups of farmers. Compared to other rice variety adopters, farmers who grow Pusa 44 have 3.61 quintals/acre higher yields. They have similar costs of cultivation, and thus the Pusa 44 adopters have significantly higher net returns. The difference in net returns is an amount of Rs. 5,447 per acre on average. This is likely to be an important influence in the choice of growing Pusa 44.

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[2] Note that we have shown this in Table 4 below.

Table 2: Summary statistics and difference in means for Pusa 44 adopters vs other variety adopters

Variable	Mean (Pusa44)	SD (Pusa44)	Mean (Other)	SD (Other)	Difference in means	Std. Error
1. Farmer/Household characteristics						
Age	46.08	(14.1)	45.95	(14.83)	0.13	(1.02)
Gender (1=male)	0.99	(0.09)	0.99	(0.09)	0.00	(0.01)
Caste (1=GEN)	0.96	(0.2)	0.93	(0.25)	0.03*	(0.02)
Family size	6.31	(2.72)	6.53	(2.97)	-0.22	(0.2)
Illiterate/Below primary	0.16	(0.37)	0.14	(0.35)	0.02	(0.03)
Primary education	0.12	(0.32)	0.13	(0.34)	-0.02	(0.02)
Middle education	0.15	(0.36)	0.18	(0.39)	-0.03	(0.03)
Secondary education	0.29	(0.45)	0.28	(0.45)	0.01	(0.03)
Higher secondary education	0.18	(0.39)	0.17	(0.37)	0.01	(0.03)
Graduation and above	0.10	(0.3)	0.10	(0.3)	0.00	(0.02)
Own land	0.97	(0.18)	0.98	(0.16)	-0.01	(0.01)
Marginal farmer	0.08	(0.28)	0.08	(0.28)	0.00	(0.02)
Small farmer	0.19	(0.39)	0.18	(0.38)	0.01	(0.03)
Medium farmer	0.29	(0.45)	0.29	(0.45)	0.00	(0.03)
Large farmer	0.44	(0.5)	0.45	(0.5)	-0.01	(0.03)
Own bank account	0.98	(0.13)	0.97	(0.16)	0.01	(0.01)
Own kisan credit card	0.68	(0.47)	0.66	(0.47)	0.02	(0.03)
Primary occupation is agriculture	0.94	(0.25)	0.93	(0.26)	0.01	(0.02)
Experienced crop loss	0.22	(0.42)	0.29	(0.45)	-0.06**	(0.03)
Outstanding debt	0.82	(0.39)	0.76	(0.42)	0.05*	(0.03)
2. Source of seed purchase						
Private	0.66	(0.48)	0.60	(0.49)	0.06	(0.03)
Government	0.03	(0.18)	0.07	(0.26)	-0.04**	(0.02)
Local seed dealer	0.25	(0.43)	0.29	(0.45)	-0.04	(0.03)
3. Source of information about the variety						
Relative/farmer	0.37	(0.48)	0.34	(0.48)	0.02	(0.03)
Village zamindar	0.29	(0.45)	0.31	(0.46)	-0.02	(0.03)
Input dealer	0.12	(0.32)	0.11	(0.31)	0.01	(0.02)
Print media	0.03	(0.18)	0.05	(0.22)	-0.02	(0.01)
Others	0.12	(0.33)	0.10	(0.3)	0.02	(0.02)
4. Main reason for adoption of the variety						
Grain yield	0.67	(0.47)	0.57	(0.5)	0.10***	(0.03)
Reliability of buyers	0.09	(0.29)	0.09	(0.29)	0.00	(0.02)
Selling price	0.08	(0.28)	0.06	(0.24)	0.02	(0.02)
Earliness in maturity	0.04	(0.2)	0.08	(0.27)	-0.04**	(0.02)
Other reasons[3]	0.11	(0.31)	0.20	(0.4)	-0.09***	(0.03)
5. Farm and Production characteristics						
Rice variety area (acre)	9.41	(12.8)	6.23	(6.2)	3.18***	(0.67)
Use Laser Land Leveller	0.64	(0.48)	0.64	(0.48)	0.00	(0.03)
Use Zero Tillage	0.03	(0.18)	0.03	(0.17)	0.01	(0.01)
Own tubewell	0.99	(0.12)	0.97	(0.17)	0.01	(0.01)
Depth of water in tubewell (feet)	93.97	(37.51)	71.30	(40.67)	22.67***	(2.75)
Water level decline over 10 years (feet)	36.17	(22.95)	25.61	(18.02)	10.56***	(1.41)
Own electric pump	0.97	(0.17)	0.91	(0.28)	0.06***	(0.02)
Pump size per hectare (hp)	4.98	(4.45)	3.68	(4.1)	1.31***	(0.3)
Total cost of cultivation (all inputs)	11848.69	(2228.51)	12048.41	(6253.63)	-199.72	(347.48)
Rice variety yield (quintal/acre)	31.23	(4.05)	27.62	(5.19)	3.61***	(0.33)
Net returns (Rs. /acre)	35281.22	(6362.38)	29833.93	(10073.81)	5447.29***	(608.57)
N (Total =839)	354		485			

Note: *, **, *** mean statistically different from 0 at 10%, 5%, 1% levels of significance respectively.

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[3] Other reasons include selling price of variety, fertilizer requirement, water requirement, grain size and resistance to pests.

Since the selling price does not differ for the main rice varieties, and the costs of cultivation are not significantly different across varieties, the difference in net returns can be attributed to the difference in yields.

Figure 5 shows the kernel density plots for yields of Pusa 44 and other rice varieties. The distribution of Pusa 44 yields is to the right of the distribution of other variety yields, with larger yield values for all the Pusa 44 farmers. In fact, the yields of Pusa 44 are higher than yields of other varieties across the entire distribution of land holding sizes. This is shown in **Table 3** below, where we compare the mean yields across the farm size categories for each of the main varieties. The difference in mean yields between Pusa 44 and other main rice varieties, is statistically significant across all the farmer categories, with Pusa 44 farmers having higher yields. We observe that yields increase with farm size. Overall, large farmers have the highest yields for each variety, and Pusa 44 farmers have higher yields than other variety farmers. However, marginal farmers growing Pusa 44, PR 114 and PR 121 have similar yields and these are not significantly different.

Table 3: Rice variety yields by farm sizes and t-tests for difference in means

Farmer type	Rice Variety				
	Pusa 44	PR 114	PR 121	PR Others	Others
MARGINAL					
Mean Yield	27.57	26.44	26.50	20.88	19.85
Difference from Pusa 44		1.12	1.06	6.69***	7.72***
S. E		(1.94)	(1.97)	(2.34)	(2.39)
SMALL					
Mean Yield	31.31	27.00	26.92	27.00	28.28
Difference from Pusa 44		4.31***	4.40***	4.31***	3.02**
S. E		(1.02)	(1.01)	(1.05)	(1.18)
MEDIUM					
Mean Yield	31.55	27.70	26.69	27.24	27.55
Difference from Pusa 44		3.85***	4.86***	4.30***	4.01***
S. E		(0.86)	(0.87)	(0.66)	(0.93)
LARGE					
Mean Yield	31.68	29.53	28.28	27.96	29.10
Difference from Pusa 44		2.15***	3.40***	3.71***	2.57***
S. E		(0.51)	(0.54)	(0.65)	(0.61)

Note: *, **, *** mean statistically different from 0 at 10%, 5%, 1% levels of significance respectively.

Figure 5: Kernel Density Plot of Yields: Other varieties vs Pusa 44
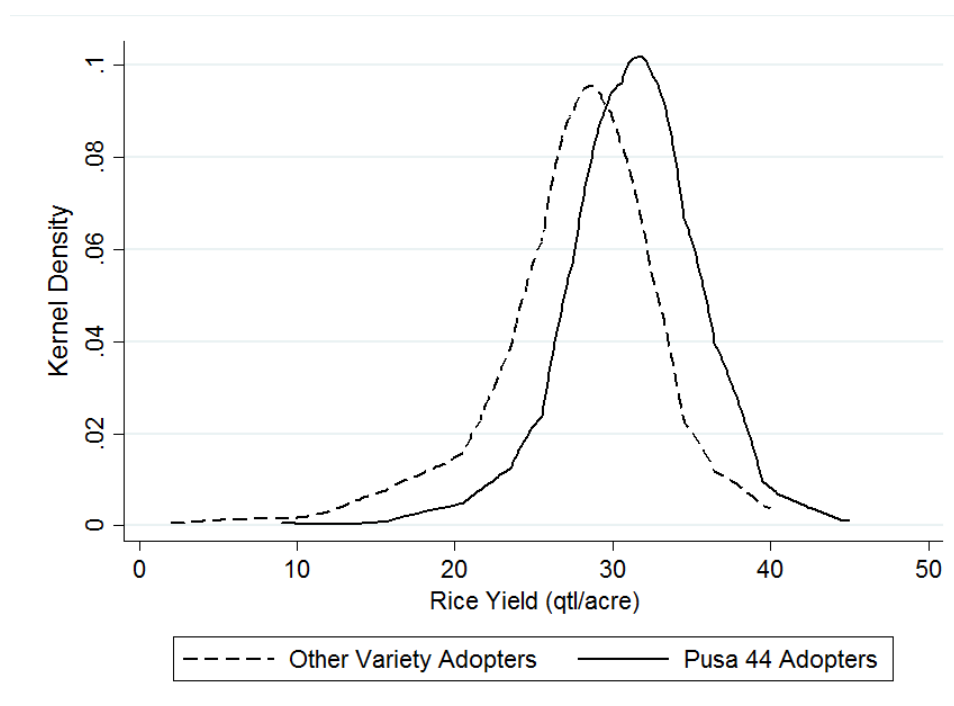
A possible theory, different from the private benefits theory explored so far, for why farmers continue to grow Pusa 44 could be that they are late adopters or laggards in the technology adoption cycle. This could be because of their demographic, economic or psychological characteristics. The idea behind the technology adoption and diffusion cycle dates to the work of Beal and Bohlen, 1957 and has been developed by several others over the years. The most prominent among them is the work of Rogers, 1995. To test whether the farmers who are growing Pusa 44 are technology laggards, we summarize the distribution of basmati and wheat variety adoption for Pusa 44 farmers and Other rice variety farmers. This is shown in **Table 4** below. From our sample of rice farmers, 99 farmers who grow Pusa 44 also grow basmati rice. 245 farmers who grow other rice varieties also grow basmati rice. For wheat, 340 Pusa 44 farmers are growing wheat whereas 457 other rice variety farmers are growing wheat. So, we want to look at the basmati and wheat variety choice of these two group of farmers. If Pusa 44 adopters are technology laggards compared to other farmers, we would expect them to be growing older basmati and wheat varieties as well. The first thing to note from the second column in the table is that the basmati and wheat varieties popular in Punjab are much newer compared to the rice varieties. Release years go from 2005 to as recent as 2014. Wheat variety turnover seems to be the fastest. HD 2967 is the most widely adopted wheat variety, and it was released in 2011. We then note from columns 3 and 4 that the percentage of farmers growing each basmati and wheat variety are similar across the two groups. Pusa 44 farmers are not more

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likely to be growing different or older basmati or wheat varieties as compared to other farmers. In fact their average age for wheat, their main crop in the next sowing season after rice, is only 4.5 years. This rules out the possibility that they are laggards in general.

Table 4: Basmati and Wheat varieties grown by Pusa 44 adopters and other rice adopters

		Pusa 44 Adopters	Other Variety Adopters
Number of farmers growing basmati		99	245
Number of farmers growing wheat		340	457
Major varieties of Basmati and Wheat	*Release Year*	*Percentage farmers*	*Percentage farmers*
Basmati Variety			
Pusa 1121	2005	97%	95%
Pusa 1401	2008	1%	3%
Pusa 1509	2015	0%	1%
Wheat Variety			
HD 2967	2011	76%	74%
HD 3086	2014	13%	14%

In our sample districts, after harvesting rice, farmers grow wheat in the next crop season. It is possible that due to the longer duration of Pusa 44, the sowing of the wheat crop is affected. This could reflect in poorer wheat yields for Pusa 44 farmers implying that the net benefits acquired from growing the higher yielding rice variety are compensated by losses in wheat productivity. In **Table 5**, we test this hypothesis using a simple t-test comparing wheat yields for Pusa 44 adopters vs other variety adopters. We find that Pusa 44 adopters have slightly lower wheat yields and wheat areas, but this difference is not statistically significant. Hence the productivity of wheat is not significantly affected by growing Pusa 44 and we can say that the Pusa 44 farmers still enjoy overall net private benefits compared to rice farmers growing other varieties.

Table 5: Comparing wheat yields for Pusa 44 adopters vs other rice variety adopters

Variable	Mean (Pusa44)	SD (Pusa44)	Mean (Other)	SD (Other)	Difference in means	Std. Error
Wheat variety yield (qtl/acre)	24.41	(9.35)	25.12	(10.65)	-0.71	(0.67)
Wheat variety area (acre)	10.92	(10.01)	11.49	(11.43)	-0.56	(0.72)
N (Total = 797)	340		457			

Note: *, **, *** mean statistically different from 0 at 10%, 5%, 1% levels of significance respectively.

4. Modelling the drivers of adoption of Pusa 44

To further investigate the factors affecting adoption of Pusa 44, we use a Linear Probability Model (LPM) and a Probit model. The dependent variable in the analysis is the probability that a farmer grows Pusa 44. It is a binary variable equal to 1 if a farmer is a Pusa 44 adopter, and 0 otherwise. We control for different sets of variables that can affect adoption: farmer and household characteristics, sources of variety information, sources of seed purchase, soil types, and location. LPM allows for easy interpretation of the regression coefficients as percentage changes. Probit corrects for some of the shortcomings of LPM, and uses maximum likelihood estimation. We use it to show the robustness of our LPM result. **Table 6** reports the results from our estimation. Only the variables that significantly explain the adoption decision are shown here. The complete version with all coefficients can be found in the Appendix. However, it is also of interest to understand which factors do not affect adoption. We find that most of the farmer and household characteristics do not explain the adoption of Pusa 44. In the model, these include age, gender, caste, education level, bank account, kisan card, primary occupation, crop loss, and household debt. Additionally, sources of variety information, which include other farmers, input dealers, public and private extension, also do not explain the likelihood of Pusa 44 adoption.

From the specification in column 1 of **Table 6**, we find that medium and large farmers are significantly less likely to adopt Pusa 44, by 10 and 11% respectively, as compared to marginal farmers. We earlier showed that net returns from growing Pusa 44 are higher than other varieties. Marginal and small farmers may be getting this advantage from growing Pusa 44 in smaller land. Farmers who use laser land leveller on their fields are 5% less likely to be Pusa 44 adopters. LLL is a water saving technology, and farmers using it might be facing scarcer water conditions, that would make them more likely to grow rice varieties other than Pusa 44. Farmers who own tubewells are 25% more likely to adopt Pusa 44 compared to those who do not own tubewells. This variable captures the availability of water for irrigation. Farmers with more abundance of ground water resources, are more likely to grow a water intensive rice variety like Pusa 44. Note that although we had information on water levels in the farmers' tubewells, we have not controlled for this as there may be reverse causality. The same holds for the size of farmers' pump sets for drawing water. Further, farmers who purchase/obtain seeds from a government source, whether a research institution, KVK, or from the agriculture department, are 18% less likely to grow Pusa 44 as compared to other rice varieties. This is indicative of the effort by the State to promote newer rice varieties. However, the percentage

of farmers reporting this source is very small, as we saw from **Table 2**, and more government intervention is needed to push farmers to adopt newer varieties. Our result shows that this can be very effective in tackling the non-adoption. The usual sources from where farmers purchase seeds, like private dealers, cater to the farmers' higher demands for Pusa 44 and would not consider the social costs associated with it. Controlling for the soil type as an agronomical variable that could influence growing a variety, we find that farmers having fields with loam soil are more likely to grow Pusa 44 than those with other types of soil. Loam soil is highly fertile and common in Punjab. We also add district fixed effects in our model to control for differences in adoption across districts, due to infrastructure, governance, and other unobserved factors. We find that farmers in Moga, Barnala, Sangrur, Ludhiana, and Muktsar districts, are more likely to be Pusa 44 adopters. This corresponds with the strong locational clustering that we saw in **Figure 2** and **3**. These are the high adoption districts of central Punjab. Column 3 reports results from a Probit model, where we have the same dependent and control variables. We find that the results support those obtained from the LPM, with the same signs. We do not interpret the magnitude of the effect of significant variables from the Probit coefficients, only their signs and levels of significance.

In column 3 and 4 we add variables capturing farmers' perception about variety traits as additional controls. In our survey, we asked farmers to rank a generalized list of seed variety traits on a scale of 0 to 10 where 0 means that the trait is the least important to the farmer in deciding which variety to grow, and 10 means that the trait is the most important. The list of traits given for ranking were: grain yield, water requirement, pest resistance, maturity period, chemical fertilizer requirement, labour requirement, grain size, cooking quality, taste, less breakage and resistance to lodging. From our summary statistics in **Table 1** and **Table 2**, we know that yield, water requirement and maturity period are the unique traits/features of Pusa 44 variety. We create a variable called 'Yield is the most important trait' which is equal to 1 if a farmer gives a high rank to yield[4]. Similarly, we create 'Water requirement is the most important trait' if a farmer gives a high rank to water, 'Earliness in maturity is the most important trait' if a farmer gives the highest rank to maturity period, and so on for all the other traits. Since Pusa 44 has higher yields, is more water intensive, and has a longer maturity period than other varieties, we expect a farmer's perception about these traits to affect the adoption decision, apart from the other variables that we had already controlled for. Column 3 shows

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[4] We define 'high rank' as ranked 8, 9 or 10 by the farmer. Since the scale is subjective, we believe this range of ranks covers the farmers who value the variety trait in question the most.

the coefficients from the LPM. We find that the most of the other previously significant control variables remain significant in explaining adoption of Pusa 44. Additionally, if a farmer perceives yield to be the most important variety trait in his choice of a variety, he/she is 9% more likely to be a Pusa 44 adopter. Farmers' perceptions about all the other variety traits, are not significant determinants of adoption of Pusa 44 variety. Hence, farmers who value yield the most out of all variety traits, are the ones choosing to grow Pusa 44. Column 4 reports the results from a Probit model with the same control variables as those in Column 3. The sign of coefficients matches those found from the LPM, adding to the robustness of our results.

We try to further understand the concentration of Pusa 44 variety in the central Punjab districts. There are a few facts that we have already noted from the analysis above: 1) Central Punjab districts with high adoption of Pusa 44 have more extensive ground water use. Farmers in this region have deeper water levels in their tubewells and own larger pump sets. 2) Central Punjab is the main rice belt of Punjab, with a larger number of rice farmers overall than in other parts of Punjab. Additionally, we find two more things. These are depicted in **Table 7** below. Here we summarize the findings from it, continuing the above numbering sequence. 3) A significantly lesser proportion of farmers from central Punjab are growing basmati rice. This means that more of them are primarily non-basmati rice growers. Hence, farmers from other parts of Punjab are more likely to be growing basmati rice along with non-basmati rice, than central Punjab farmers. 4) Farmers in central Punjab mainly grow only one rice variety each. As we have seen, this is the Pusa 44 variety. Others diversify more: Farmers outside of central Punjab are more likely to be growing 2 or 3 non-basmati rice varieties. Hence, central Punjab mainly comprises of non-basmati rice farmers, who grow Pusa 44 as their primary rice variety.

Table 6: Adoption of Pusa 44: Linear Probability Model and Probit Model

Dependent Variable: Probability (Pusa 44)	(1) LPM	(2) Probit	(3) LPM	(4) Probit
Farm size (Base = Marginal farmer)				
Small farmer	-0.09	-0.38	-0.10	-0.44*
	(0.06)	(0.24)	(0.06)	(0.24)
Medium farmer	-0.10*	-0.44**	-0.11*	-0.49**
	(0.06)	(0.22)	(0.06)	(0.22)
Large farmer	-0.11*	-0.48**	-0.12**	-0.55**
	(0.06)	(0.22)	(0.06)	(0.22)
Use LLL	-0.05*	-0.19	-0.05*	-0.20
	(0.03)	(0.12)	(0.03)	(0.13)
Own tubewell	0.25**	1.08**	0.27**	1.21**
	(0.11)	(0.52)	(0.11)	(0.51)
Source of seed purchase				
Private	-0.05	-0.18	-0.03	-0.10
	(0.06)	(0.23)	(0.05)	(0.22)
Government	-0.18**	-0.70**	-0.20**	-0.77**
	(0.09)	(0.34)	(0.09)	(0.35)
Farmer's perception about variety traits				
Yield is the most important trait			0.09***	0.38***
			(0.03)	(0.13)
Soil types (Base = Black soil)				
Loam soil	0.12**	0.46**	0.08*	0.36*
	(0.05)	(0.19)	(0.05)	(0.20)
District Fixed effects				
Barnala	0.75***	2.54***	0.74***	2.51***
	(0.11)	(0.64)	(0.11)	(0.64)
Ludhiana	0.51***	1.78***	0.45***	1.53***
	(0.09)	(0.59)	(0.10)	(0.59)
Moga	0.86***	3.04***	0.84***	3.00***
	(0.08)	(0.60)	(0.08)	(0.59)
Muktsar	0.36***	1.43**	0.34***	1.38**
	(0.10)	(0.59)	(0.10)	(0.59)
Sangrur	0.69***	2.35***	0.67***	2.28***
	(0.08)	(0.58)	(0.08)	(0.57)
Other Control Variables	Yes	Yes	Yes	Yes
Observations	839	839	839	839
R-squared	0.42		0.43	
Pseudo R-squared		0.36		0.38

Note: Heteroscedasticity robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1
'Other Control Variables' are farmer characteristics like age, gender, caste, education level, bank account, kisan card, primary occupation, crop loss, debt; sources of information about variety; perception of all variety traits; soil type; all district fixed effects. **The full version of this table with all controls is shown in Table 8 in the Appendix.**

Table 7: Comparing Central Punjab with Other Districts

Region	% Non-Basmati Rice farmers also growing Basmati Rice	% Non-Basmati Rice farmers growing more than 1 non-basmati rice variety
Central Punjab Districts	31%	0%
Other Districts	54%	16%

5.   **Conclusion**

The high rate of adoption of Pusa 44, and consequently the resistance of farmers to switch to newer, improved rice varieties, is a concern for Punjab, in the background of its depleting ground water resources. This variety inertia in the agriculturally progressive state of Punjab, is not explained by any of the common determinants of technology adoption found in the literature. From our primary survey on variety adoption in 12 sample districts, we find that the private benefits from growing Pusa 44 far exceed the private costs. Additionally, there are negative externalities associated with growing this variety, as it requires more water, pesticides, and other inputs. Farmers benefit from higher yields of Pusa 44, while incurring a social cost. They have deeper water tables, and larger pump sets to draw water, resulting in a set up for ground water exploitation.

The important drivers of adoption of Pusa 44 are farmers' perception of yield as the most important variety trait and the abundance of ground water. Emphasis on private benefits from higher yields, coupled with free electricity and easy availability of ground water, skews farmers' choice of variety in favour of Pusa 44. This is seen more prominently in the districts of central Punjab, which is the main rice belt. We find that the farmers in this region are growing only one non-basmati rice variety, namely Pusa 44. Only a small proportion of them also grow basmati rice. This is in contrast with the other rice growing districts of Punjab, where farmers diversify more in terms of rice varieties, growing both non-basmati and basmati rice, more than one non-basmati rice variety, and newer varieties.

We also find evidence that farmers who obtain seeds from government sources, are less likely to grow Pusa 44. However, only 7% of farmers growing newer varieties report government as a source for their seeds. This emphasizes the need for stronger government intervention, along with more geographical coverage in promoting newer rice varieties. The central Punjab districts with high adoption of Pusa 44 like Moga, Muktsar, Barnala, Sangrur, and Ludhiana, should be targeted. Moreover, we find that farmers using Laser Land Leveller technology, are less likely to be Pusa 44 adopters. This shows that the knowledge and use of this water saving technology can probe farmers to adopt less water intensive varieties. These farmers are more likely to consider water requirement as an important variety trait, leading them to choose varieties other than Pusa 44. Promotion of this technology can contribute to a perception change and thus a variety switch. Smaller farmers should also be targeted, as they have more incentive to grow Pusa 44, taking advantage of more yield from lesser space. We recommend incentivizing them

to switch to newer varieties, that require lesser water but do not suffer from a yield disadvantage compared with Pusa 44. At present a few varieties with comparable yields are present in the market. Our results highlight that the adoption of these varieties is negligible in 2016-17, and that the state must push for increasing their adoption. Policy intervention is important in this set up where the ground water resource cost is not fully realized, farmers prefer growing Pusa 44, and growing Pusa 44 results in negative externalities.

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Appendix

Table 8: Full Table for Adoption of Pusa 44 using Linear Probability Model and Probit Model

Dependent Variable: Probability (Pusa 44)	(1) LPM	(2) Probit	(3) LPM	(4) Probit
Farmer and household characteristics				
Age	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Gender	0.01	0.07	-0.03	-0.03
	(0.08)	(0.42)	(0.08)	(0.43)
Caste	-0.01	-0.01	-0.01	0.01
	(0.05)	(0.23)	(0.05)	(0.22)
Primary education	-0.01	-0.05	-0.02	-0.06
	(0.05)	(0.20)	(0.05)	(0.20)
Middle education	-0.05	-0.24	-0.07	-0.30
	(0.05)	(0.19)	(0.05)	(0.20)
Secondary education	0.05	0.23	0.04	0.24
	(0.05)	(0.18)	(0.05)	(0.19)
Higher secondary and above	-0.01	-0.06	-0.01	-0.09
	(0.05)	(0.20)	(0.05)	(0.20)
Own land	-0.13	-0.58*	-0.11	-0.56
	(0.08)	(0.34)	(0.09)	(0.35)
Small farmer	-0.09	-0.38	-0.10	-0.44*
	(0.06)	(0.24)	(0.06)	(0.24)
Medium farmer	-0.10*	-0.44**	-0.11*	-0.49**
	(0.06)	(0.22)	(0.06)	(0.22)
Large farmer	-0.11*	-0.48**	-0.12**	-0.55**
	(0.06)	(0.22)	(0.06)	(0.22)
Own bank account	0.03	0.08	0.03	0.07
	(0.09)	(0.40)	(0.09)	(0.37)
Own kisan card	-0.01	-0.03	0.00	0.00
	(0.03)	(0.13)	(0.03)	(0.13)
Primary occupation is agriculture	-0.01	0.01	-0.01	-0.00
	(0.05)	(0.23)	(0.06)	(0.23)
Crop loss	-0.03	-0.10	-0.03	-0.06
	(0.04)	(0.14)	(0.04)	(0.15)
Outstanding debt	0.04	0.17	0.03	0.12
	(0.04)	(0.15)	(0.04)	(0.16)
Use LLL	-0.05*	-0.19	-0.05*	-0.20
	(0.03)	(0.12)	(0.03)	(0.13)
Use ZT	0.13	0.55	0.13	0.59*
	(0.08)	(0.34)	(0.08)	(0.32)
Own tubewell	0.25**	1.08**	0.27**	1.21**
	(0.11)	(0.52)	(0.11)	(0.51)
Own electric pump	0.01	-0.04	0.00	-0.12
	(0.07)	(0.33)	(0.07)	(0.33)
Source of information				
Relative or another farmer	0.02	0.10	0.01	0.06
	(0.06)	(0.22)	(0.06)	(0.22)
Village zamindar	-0.03	-0.11	-0.03	-0.12
	(0.06)	(0.22)	(0.06)	(0.23)
Input dealer	-0.00	0.01	-0.02	-0.06
	(0.07)	(0.27)	(0.07)	(0.27)
Print media	-0.06	-0.15	-0.07	-0.21
	(0.10)	(0.35)	(0.10)	(0.36)
Other sources	-0.03	-0.10	-0.04	-0.11
	(0.06)	(0.25)	(0.06)	(0.25)
Source of seed purchase				
Private	-0.05	-0.18	-0.03	-0.10
	(0.06)	(0.23)	(0.05)	(0.22)
Government	-0.18**	-0.70**	-0.20**	-0.77**
	(0.09)	(0.34)	(0.09)	(0.35)
Local shopkeeper	0.01	0.04	0.01	0.08
	(0.06)	(0.25)	(0.06)	(0.24)
Farmer's perception about variety traits:				

	(1)	(2)	(3)	(4)
Yield is the most important trait			0.09***	0.38***
			(0.03)	(0.13)
Water requirement is the most important trait			0.00	-0.02
			(0.05)	(0.18)
Earliness in maturity is the most important trait			0.06	0.15
			(0.07)	(0.23)
Grain size is the most important trait			0.06	0.22
			(0.05)	(0.17)
Dry fodder yield is the most important trait			-0.12	-0.35
			(0.10)	(0.36)
Resistance to pests is the most important trait			-0.04	-0.15
			(0.08)	(0.26)
Resistance to lodging is the most important trait			-0.01	-0.03
			(0.04)	(0.16)
Fertilizer requirement is the most important trait			0.10	0.37
			(0.07)	(0.24)
Labour requirement is the most important trait			-0.02	-0.11
			(0.06)	(0.22)
Selling price is the most important trait			-0.01	-0.01
			(0.06)	(0.19)
Buyers' demand is the most important trait			-0.01	-0.05
			(0.04)	(0.14)
Cooking quality is the most important trait			-0.01	0.03
			(0.05)	(0.17)
Taste is the most important trait			0.01	0.04
			(0.04)	(0.15)
Soil types (Base = Black)				
Clay	-0.01	-0.07	-0.01	-0.09
	(0.04)	(0.16)	(0.04)	(0.16)
Loam	0.12**	0.46**	0.08*	0.36*
	(0.05)	(0.19)	(0.05)	(0.20)
Red Soil	0.08	0.25	0.07	0.21
	(0.06)	(0.22)	(0.07)	(0.23)
Sand	0.05	0.21	0.04	0.18
	(0.04)	(0.15)	(0.04)	(0.16)
Sandy	-0.02	-0.10	-0.02	-0.08
	(0.05)	(0.21)	(0.05)	(0.21)
District Fixed effects				
Barnala	0.75***	2.54***	0.74***	2.51***
	(0.11)	(0.64)	(0.11)	(0.64)
Fatehgarh Sahib	0.20*	0.88	0.13	0.58
	(0.11)	(0.63)	(0.11)	(0.63)
Firozpur	-0.01	-0.27	-0.02	-0.33
	(0.08)	(0.60)	(0.08)	(0.60)
Faridkot	0.24**	1.08*	0.23**	1.03*
	(0.11)	(0.62)	(0.11)	(0.62)
Gurdaspur	-0.03	-0.44	-0.06	-0.60
	(0.08)	(0.67)	(0.08)	(0.66)
Jalandhar	0.22**	1.00*	0.16*	0.74
	(0.09)	(0.59)	(0.09)	(0.59)
Ludhiana	0.51***	1.78***	0.45***	1.53***
	(0.09)	(0.59)	(0.10)	(0.59)
Moga	0.86***	3.04***	0.84***	3.00***
	(0.08)	(0.60)	(0.08)	(0.59)
Muktsar	0.36***	1.43**	0.34***	1.38**
	(0.10)	(0.59)	(0.10)	(0.59)
Sangrur	0.69***	2.35***	0.67***	2.28***
	(0.08)	(0.58)	(0.08)	(0.57)
Tarn Taran	-0.03	-0.31	-0.03	-0.33
	(0.09)	(0.70)	(0.09)	(0.70)
Constant	0.01	-1.73*	0.03	-1.67*
	(0.20)	(1.01)	(0.21)	(0.99)
Observations	839	839	839	839
R-squared	0.42		0.43	
Pseudo R-squared		0.36		0.38

Note: Heteroscedasticity robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1