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Back to the plough: Women managers and farm productivity in India ☆

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ABSTRACT

In India, role of women as farm managers has been veiled behind image of men as primary decision makers on farms. Data shows that approximately 8% farm households had women farm managers in India in 2004, and this number increased to 11% in 2011. This rising phenomenon of farm management by women begets an in depth understanding about these farms, including, differentials in productivity levels across men and women managers. This paper uses three measures to capture productivity – production value, profit value and crop specific yields. Results show that total farm production and profits are lower by approximately 11% in households where women manage farms. This falls to 7% when controls for crop choice, input usage, location and farmer characteristics are included. The main mediating factors in explaining the productivity gap are crop choice and input usage, explaining almost 45% of the productivity gap. Further, the paper provides suggestive evidence on mechanisms contributing to the remaining productivity difference that cannot be explained by differences in observed characteristics. It shows that inadequate experience of women farm managers in agricultural production processes can be an important factor behind the remaining gap. The study makes two contributions to the literature – one, it is the first quantitative study in the Indian context on gender differentials in farm productivity and second, it applies semi-parametric decomposition techniques to look at the productivity differentials along the entire distribution.

1. Introduction

Economists have been interested in gender gaps in employment, wages, access to resources and productivity to understand sources of disadvantage faced by almost half of the world's population. An extensive body of work looks at the difference in female and male productivity in agriculture. Doss (2015) and Quisumbing (1996) provide a detailed review of the studies. There are two strands within this literature. One looks at the gender difference in labor productivity in cultivation of a crop. Second looks at the crop productivity of lands either owned or managed by female and male farmers. Udry (1996) was one of the earliest studies in this literature. It examined differences in productivity of plots controlled by men and women within the same household, and growing the same crop in Africa. Most studies find that productivity of female managed plots is lower than those controlled by males, and this difference either becomes very small or vanishes when controls for access to productive resources are included.

A large body of literature for Sub-Saharan Africa has developed in the last two decades. Recent studies include De la O Campos et al. (2016) for Uganda; Ali et al. (2015) for Uganda; Aguilar et al. (2015) for Ethiopia; Kilic, Palacios-Lopez and Goldstein (2015) for Malawi; Oseni et al. (2015) for Nigeria; Backiny-Yetna and McGee (2018) for Niger; Slavchevska (2015) for Tanzania; Palacios-López and López (2015) for Malawi; Kazianga and Wahhaj (2013) for Burkina Faso and Peterman (2011) for Nigeria and Uganda. There are few studies that analyze this dimension of gender gap in other regions. There is only one study on rice production in Philippines by Koirala, Mishra and Mohanty (2015) which looks into the difference in productivity of male and female headed farm households. On the basis of a review of many such studies FAO (2011) states that "If women had the same access to productive resources as men, they could increase yields on their farms by 20–30 percent."

Increasing smallholder agricultural productivity is one of the tools for poverty reduction in rural areas. Productivity on Indian farms is lower than world average and agricultural policy in India needs to be reshaped to cater to emerging needs of women farmers. Currently there is little space in the policy to make provision for differential needs of women who manage their farms. This is largely because of invisibility of these women as primary decision makers on farm matters from the discourse. A part of it is attributable to paucity of data regarding this facet of cultivator

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households in India. Globally, shares of women farm operators range from a high of 18% in Latin America and the Caribbean to a low of 4% in Oceania. South Asia shows a proportion of 12% (FAO, 2011).[1]

As per the Indian agriculture census 2010–11, women farmers operate 12.78% of operational land holdings and 10.34% of the operational area in India. In 1995–96, these figures stood at 9.5% of land holdings and 7.2% of operational area. According to Indian Human Development Survey (IHDS), proportion of households where women manage farms increased from 8.3% in 2004 to 11% in 2011. Clearly, the levels are low but women are gaining ground in farm management. Mahajan (2018) looks at the determinants of this rise in incidence of women farm managers and finds that male migration is one of the important reasons behind the observed growth in their numbers over time. There is no evidence of what might be the implications of this for food security. A recent study by Agarwal (2018), using data from two states of India, shows that group farming by women can potentially help overcome the constraints faced by individual women farmers.

This paper provides estimates for gender differences in agricultural farm productivity in India, where agriculture is still a predominant provider of employment in rural areas, housing 70% of Indian population. It examines to what extent these gaps can be explained by observed differences in characteristics between households where men and women manage farms. From the perspective of both gender and food security this question assumes importance. This study contributes to the literature in two ways – it is the first study to provide these estimates for India and secondly, it undertakes a non-parametric decomposition along the entire productivity distribution, and not only at the mean levels of productivity. Apart from productivity, it also looks at differences in farm profits since input decisions are taken to maximize profits and not production value. Efficiency requirements on farm should then relate to profitability and not value of output only. It also provides suggestive evidence to ascertain whether inadequate knowledge and experience of women farm managers is a mechanism behind residual effects, which cannot be explained by observed characteristics. This is done by exploiting established gender roles across crops in India and regional variation in cultural barriers to women's participation in the agricultural labor market in India.

The paper is organized as follows. Section 2 presents a brief literature review on the existing evidence for other countries and the Indian context. Section 3 elucidates the data used in the analyses and the empirical strategy, along with a description of variables. The empirical strategy is detailed in Section 4 and the regression results are discussed in Section 5. Section 6 checks for robustness of the results using a bound analyses and conducts a semi-parametric decomposition of productivity differentials along the entire productivity distribution. It also provides evidence for possible mechanisms behind the productivity gaps that remain after inclusion of all controls in the regression. Conclusions are gathered in Section 7.

2. Background

2.1. Literature review

The literature employs two types of methodologies to assess the gender differential in agricultural productivity. The first uses household-level information and outcomes and relates it to either the gender of the household head or gender of the person who makes farm management decisions in the household (Quisumbing, 1996; Doss, 2015; Peterman et al., 2011). Using data on household head is more common since most surveys capture this information. These studies assume that decision making within the households follows a unitary setting[2] and soil quality differences across households in a study area are negligible (Schultz, 2001).[3]

The second set of studies use plot level information within a household. This is due to prevalence of differential management of plots within a household by men and women in Sub-Saharan Africa. Such a setting allows one to control for household-crop level heterogeneity in a regression framework. The causal estimate is identified using within household variation in productivity differences across male and female managed plots cultivated with the same crop. These have been the most influential studies in terms of bringing out pareto-inefficiency within household allocation of resources to production. Recent studies use Blinder-Oaxaca decomposition to decompose the difference in productivity into an endowments part (due to inputs and other household characteristics) and the second part due to structural differences (unexplained part).

A few studies find that gender differentials are significant even after controlling for input usage and other characteristics across plots (Saito, Mekonnen, & Spurling, 1994 for Nigeria; Udry, 1996 for Burkina Faso; Peterman et al., 2011 for Uganda) while others find that the differential disappears after input controls are included (Kazianga and Wahhaj 2013 for Burkina Faso; Saito, Mekonnen, & Spurling, 1994 for Kenya; Gilbert, Sakala, & Benson 2002 for Malawi; Akresh 2005 for Burkina Faso; Goldstein & Udry, 2008 for Ghana). Most of these studies look at production value or crop yields and very few examine profits (Adesina & Djato, 1997; Goldstein & Udry, 2008). The mediating factors usually are crop choice, input usage, credit access, market access and human capital differences.

Almost the entire literature cited above is based on Africa, especially Sub-Saharan Africa. India and Africa have similarly large contributions of women to total agricultural production. Women constitute more than 40% of total agricultural workforce working in crop agriculture in Africa (Doss et al., 2015), while they contribute around a third in India. The Indian context, however, is very different from Sub-Saharan Africa when it comes to structures of farm management by women. While it is common to find variation in plot management by gender, within a household in Africa, it is much less prevalent in India or other Asian countries (Doss, 2015). In India, there is usually one person who takes most agricultural decisions across plots managed by the household, either solely, or jointly in consultation with other family members.

2.2. The Indian context

The contribution of women to agriculture in India has mostly been studied along the dimensions of unpaid family laborers and agricultural laborers. Around 73% of the rural workforce in India is engaged in agriculture (Census 2011). In terms of gender composition, about 80% (69%) of the female (male) workforce in rural India is engaged in agriculture (Census 2011). Female agricultural

[1] These figures are region level averages using data for some countries where recent data is available. There is considerable heterogeneity within each region. For example, within Caribbean, countries like Barbados have a much higher proportion of women land operators around 50% (The Association of Women in Agriculture, Barbados). Henshall (1984) finds a large variability, depending on farming systems, even within countries like Trinidad where women can control more acreage than men in cocoa cultivation.

[2] In a unitary setting the distribution of resources within a household is not taken into consideration. Household behavior is considered to be resulting from the decisions of a single individual and intra household differences in consumption and labor supply arising from different bargaining positions of the members are ignored. See Alderman et al. (1995) for details.

[3] We do not attempt a complete literature review here and interested readers can look at Quisumbing (1996), (Croppenstedt, Goldstein, & Rosas (2013) and Doss (2015) for a look at all the studies which have looked at this question.

laborers constitute 55% of the female agricultural workforce and the remainder are mostly self-employed on family farms either as unpaid laborers or operators. The discourse on feminization of agricultural labor force in India centers around increasing participation in agriculture by women, relative to men, either as self-employed on own land or working as agricultural wage laborers (Binswanger-Mkhize, 2012). This changing gender composition in agriculture has been attributed to increasing access to non-farm employment and consequent migration by men from rural areas (Tumbe, 2015). Traditionally, self-employed men owned and managed farms, while self-employed women worked as unpaid family laborers on these farms (Agarwal, 2003). Tasks like ploughing and land preparation were performed mostly by men. However, over time structural changes in rural economy have led to an increase in women managing these farmlands (Chandrasekhar, Sahoo, & Swaminathan 2017).

Research on this phenomenon has been limited largely because few datasets in India capture whether farms are operated or managed by women. Agricultural Census, National Sample Survey Organization's (NSSO) survey on Land and Livestock Holdings and IHDS are the only ones recording this information. All three surveys indicate a rise in management of farms by women. As noted earlier, IHDS shows that proportion of households where women manage farms has increased from 8.3% in 2004–05 to 11% in 2011. Here, one needs to be careful about whether women operating or managing farm lands and taking decision regarding production and input decisions, gives them any 'control' over these lands or the revenue from sold produce. The process of empowerment, as defined in Kabeer (1999) is complex, with ability to make strategic life choices at the core of it.

It is doubtful if women have any real control over these lands since most of them do not have legal titles to them. There is also considerable variation across countries within Africa in legal rights to land by gender. Out of total female adult population, 8% women own agricultural land (sole or joint) in Ghana to 35% in Niger (FAO Gender and Land Rights Database). Nationally representative estimates are not available for India, but regional ones find that even when restricting attention to rural agricultural land-owning households the incidence is in single digits for adult women (7% reported by Swaminathan et al. (2012) for Karnataka, a state of India). Agarwal (2003) argues that weak land rights for women who are increasingly responsible for cultivation, could lead to inefficiencies in production.[4] Lack of land titles can lead to lower effort by women and also lower their access to credit and other inputs.

No study has looked at women as farm managers and its implications for farm productivity in India so far. Importance of farm management in the Indian context cannot be disputed since at least 50% of households in rural areas cultivate some land. There are direct implications of rising farm management by women, due to male migration, for food security. The Economic Survey of India 2017–18 recognizes that 'feminization' of agriculture sector is happening with increasing number of women in multiple roles as cultivators and entrepreneurs. It also recognizes that in general women farmers lack access to resources like land, water, credit, technology and training. These observations noted in the Economic Survey are based on research by the Food and Agriculture Organization (FAO, 2011) across different countries but have not been quantified till date in the literature on Indian agriculture. World Economic Forum in 2017 also highlighted a need for research into this extremely important issue of gender gaps in agricultural productivity and access to inputs for India. To conduct such an analysis, a dataset needs to capture information on gender of the farm manager and farm production. Among the three surveys in India which disaggregate farm management by gender, agricultural production data is recorded only in the IHDS.

[4] In India, women's land rights remain poor because of historically gender biased inheritance laws, distribution of land by government with titles awarded to men and limited purchase of land in the market by women (Agarwal, 2003).

3. Data

This paper analyses the data from the Indian Human Development Survey (IHDS) which is a nationally representative survey conducted by the University of Maryland and the National Council of Applied Economic Research (NCAER) in 2004–05. It covers 41,554 households across 382 districts of India. It covers all States and Union Territories except Andaman and Nicobar Islands and Lakshadweep. The primary sampling units are villages in rural areas (1503 villages) and the number of rural households surveyed is 27,010.[5] The survey notes the agricultural production details in households which report cultivating land in the past year (55% of rural households report cultivating some agricultural land). The survey then records identification details of the member who primarily makes decisions regarding farm cultivation matters. Approximately 8.3% of farm households report that the primary decision maker about farm matters is a woman.

The recall period for farm production and costs was July 2003–June 2004 when interviews were conducted before December 2004. In households where interviews were conducted in 2005 the recall period was December 2003–November 2004.[6] Plot level details about crops grown in each season (*Kharif*, *Rabi* and Summer) were recorded. Information on plot level irrigation, how much area is planted under the crop, total production and price at which it was sold were also recorded. Data on usage of other inputs in farm production was recorded at household level for the entire agricultural year (man-days of labor hired, value of seeds purchased, money spent on fertilizers and manures, pesticides, water purchased for irrigation, hiring farm equipment, repayment of agricultural loans).

4. Empirical strategy

4.1. Main specification

To estimate the differential effect of a woman farm manager on agricultural productivity we include a gender dummy in the regression equation with total productivity on household farms as the dependent variable.

$$\text{Ln } O_{hv} = \beta_0 + \beta_1 \text{Woman FM}_{hv} + \beta_2 \text{lnN}_{hv} + \beta_3 C_{hv} + \beta_4 F_{hv} + \beta_5 H_{hv} + \beta_6 I_{hv} + V_v + u_{hv}$$

Here subscript 'h' refers to a household and 'v' refers to a village. The above specification tests for difference in group means of productivity across gender of the farm manager. We gradually include a comprehensive set of controls to see which controls matter in explaining the gender gap. If no controls are included, the results of the above specification are same as difference in mean productivities shown in Table 1. Variable definitions are given below:

O: Value of output per hectare of land
Woman FM: Indicator variable for the farm manager in household 'h' being a woman

[5] A second round of the survey in 2011–12 re-interviews 85% of original households and also includes new households. It covers 384 districts in the second round and includes 42,152 households. However, the crop production schedule for IHDS II is not yet publicly available and this paper uses the first round for the current analyses.

[6] More than 90% of the villages were interviewed in the same window. Controlling for village fixed effects will in the analyses hence controls for village specific weather shocks that may be correlated across households.

N: Gross cultivated area
C: Crop choice (proportion of area under each crop)
F: Farm decision maker characteristics like age, education, marital status
H: Other household characteristics like asset ownership of the household, caste, religion, demographic composition of the household (number of adult men)
I: Input used (these include: indicator variables for (a) fertilizer/manure, herbicide/pesticide, hiring water for irrigation; hiring tractors or animals for farm; credit access; ownership of tube-well, electric pump, diesel pump, bullock cart, tractor by the household; use of purchased seed (b) Proportion of cultivated land which is irrigated; hired labor days per acre; household labor days per acre (adult male, adult female, child)
V: Village Fixed effects

The main coefficient of interest in the above regression is the coefficient of the indicator variable 'Woman FM'. A negative coefficient shows that value of output produced in households where women manage farms is lower than that from households where men manage farms, even after controlling crop choice, input usage and location. Lower productivity on women managed farms despite all the controls could arise due to differences in unobservable soil quality and experience in farm cultivation and management practices. To allay the concern on soil quality, we condition all the estimates on village fixed effects. To the extent that agro-climatic variation across geographies drives the choice of crops and inputs, we are able to control for the unobservables which can affect both crop/input choice and value of production at the village level. However, a negative coefficient can still arise if there are systematic differences between gender of the farm manager and soil quality within a village.

4.2. Construction of variables

(a) Dependent variable: Production value is calculated by aggregating total value of output over all crops cultivated by a household in the reference year. Profit value is obtained by subtracting total input expenses paid in the reference year from the total value of production in the year. Both production and profit value are calculated for the all the farms cultivated by a household and are not plot specific. This is because data on expenses is captured only at the aggregate level and also because gender of the farm manager does not differ across plots cultivated by a household.

Households which undertake crop cultivation provide information on total production of each crop and the price at which each crop in a particular season was sold in the market. This price is used to impute a value to the part of produce which may have been used by the household for self-consumption. A very small proportion of households (1.4%) report no price for sale of crop or zero output.

(b) Gender of the Farm Manager in a Household: This is an indicator variable that takes a value of one if in a household a woman is the primary decision maker of farm matters. The question asked of the head of the household or the most knowledgeable person about farm matters in the household is "Who is the primary decision maker about farm matters in your house?" This variable does not vary across plots cultivated by the farm household. If a household responds that a particular member, whose gender is female (male), takes most decisions about farm matters in the household, then this household is referred to as a woman (man) managed farm household throughout this paper. This terminology is different from that used in the literature on Africa where within a household, different plots can be managed by different members or jointly cultivated.

Further to the above question, surveyors were instructed to collect information on farm production, crop prices and farm expenses from the person who is most familiar with farm decisions (the farm manager previously reported by the household) or if that person is unavailable then the household head. Information about who eventually provided the data for this module for each farm household is not given in the dataset. A lacuna which affects almost all existing data collection surveys in this literature is that they fail to account for joint production decisions (Doss, 2015). This continues to be the case for this study as well due to the nature in which data on farm management is recorded. One disadvantage of the way the question is posed in IHDS is that it does not ask whether this primary decision maker is the sole decision maker or takes decisions in joint consultation. If it were true that women, who are reported to be primary decision makers, are actually taking decisions jointly with their husbands then we should see no effects of gender on farm productivity because of measurement error in the explanatory variable.

There are other ways of defining the gender variable by taking the gender of the household head and not the person who primarily manages farms. IHDS data shows that amongst women farm managers around 77% are household heads. We prefer to use the reported farm manager's sex to define the gender variable since management is likely to be different from headship. Studies which use headship to define gender usually find existence of productivity differences but note that these differences become starker when sex of actual farm manager is used instead (Doss, 2015).[7]

Table 1 shows the difference between value of production and profits on households where men and women manage farms. On an average we find lower productivity in households where women manage farms but the difference is insignificant for both production value per acre and profits per acre (almost all studies in this literature cited in Section 2 report this finding). This finding is a result of the fact that women generally cultivate smaller landholdings in India (and worldwide). There is extensive literature which finds an inverse relationship between farm productivity and farm size (dating back to Sen, 1962). Equality of farm productivities at an aggregate level between men and women managed farms is consistent with these two observations. Essentially, women obtain higher production value on smaller plots, and hence cover the gender gap in productivity at the aggregate level. However, regression estimates later show that for same plot size, men are able to obtain a higher production value. This is the primary variable of interest in this paper, after the effect of farm size on productivity has been partialled out, and not the unconditional means reported in Table 1.

(c) Crop choice: An important mediator in most studies on gender differentials in agricultural productivity is the type of crop cultivated on a particular land. In our analyses a household could be growing multiple crops over a year. The composition of these crops is controlled for in the analyses. Table 1 shows the difference between men and women managed farm households in cultivated area and crop choice. It can be seen that women grow more cereals whereas men grow more non-food crops in India.

(d) Input usage: Plot level input usage information is only available for irrigation. Data for other inputs is available for all crops and plots combined. The mean level of input usage in households

[7] It is plausible that there is measurement error in this variable arising from households reporting women as farm managers, when they are simply taking instructions from their husbands or other male members. Also, there is no further data collected on whether the decision maker is involved alone, or jointly with other members, in the decision-making process. Such measurement error, if present, will attenuate the true effect of gender on farm productivity. Thus, if results show a significant negative effect of gender on farm productivity then this implies that in the absence of such a measurement error, this effect would have been even more negative.

Table 1
Difference between households by gender of farm manager: Output and Crop choice.

Variable	Definition	Men (N = 13105)	Women (N = 971)	Difference	
Production	Ln(production value per acre)	8.378	8.332	−0.046	
Profit	Ln(profit value per acre)	7.873	7.826	−0.047	
Area	Ln(gross cultivated area)	0.987	0.482	−0.506	***
Cereal	Proportion of area under Cereals	0.671	0.73	0.059	***
Pulses	Proportion of area under Pulses	0.079	0.071	−0.008	***
Oilseeds	Proportion of area under Oilseeds	0.092	0.06	−0.032	
Spice	Proportion of area under Spices	0.017	0.017	0	
Fruits & Veggies	Proportion of area under F&V	0.07	0.081	0.011	
Non-food	Proportion of area under Non-food crops	0.067	0.039	−0.028	***
Others	Proportion of area of cultivation under others	0.004	0.003	−0.002	*

Note: The sample includes all households which report a positive value of production in the last year. For calculation of profits, households which reported negative values were treated as missing and the effect number of observations were 11,255 for men and 804 for women managers. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.
Source: Author's calculations, IHDS I (2004).

where men and women manage farms is shown in Table 2. A simple comparison shows, women farm managers have significantly lower access to all inputs except hired equipment. Women managed farm households hire more equipment largely because their ownership of equipment (reflected in proportion of women managed farm households which own tube wells, pumps and ploughing equipment) is significantly lower than that of men managed farm households.

(e) Other controls: A description of other individual and household level control variables included in the regression analyses is given in Table 3. The statistics show that women farm managers on an average have lower education levels than men farm managers, which is largely due to overall lower schooling levels of women in rural India. There is no difference in average age of men and women farm managers and it is approximately equal to 47 years. There is a stark difference across farm households in marital status of the farm manager. Men farm managers are likely to be currently married and living with their spouse, whereas women farm managers are more likely to be widowed. The proportion of women farm managers who are currently married and living with their spouse in the village are 29%. Around 13% of women farm managers are married but their husbands have migrated from the village. In terms of wealth deciles, there is no consistent difference across men and women farm managed households. If anything, women managed households are significantly greater in upper wealth deciles than lower wealth deciles.[8] The household demographic composition shows that the number of men is significantly lower in women managed farm households. This is in line with women farm managers more likely to be widowed or having a husband who has migrated from the village.

5. Results

5.1. Value of output

Table 4 shows the results for the specification with controls for village fixed effects and crop composition. The estimates in column (1) show that value of production is lower in households where women manage farms by 11% conditional on same farm size. Table 1 shows that cultivated area is smaller in women managed farm households. As discussed before, there is an established inverse relationship between farm size and farm productivity. Smaller farms on an average have larger yields. This is reflected in a small difference at an aggregate level in value of production by gender of the farm manager (Table 1) but the difference increases once farm size is controlled in Table 4, specification (1). The results show that for the same farm size, the value of production obtained by households where women manage farms is significantly lower. Adding location specific village fixed effects reduces the gap to 10.5% and controlling for crop composition the gap in gender productivity falls to 7.7%. It is notable that women farm managers do not reside in poorer households. If anything, women managers are over represented in the upper deciles. Once controls are added for wealth, we find that gender gap in productivity increases to 8.7% (Table 5, specification 2). This implies that women farm managers despite residing in wealthier households are not able to reap benefits in terms of output value in comparison to men farm managers belonging to similar wealth status households. Adding further controls for farm manager characteristics like age, education and marital status and input usage reduces the gender gap in productivity to 7.3% (Table 5, specification 3). The main contributors to explaining the gender gap in productivity are – crop choice (33%) and input usage (13%).[9]

We next consider the heterogeneity in the effects on value of farm productivity by area cultivated, age and whether or not the manager is the household head. This is done to shed light on possible sources of disadvantage that women farm managers face. The results are shown in Table 6. We find that value of production is lower in households where women manage smaller farms rather than households where women manage larger farms. In terms of age, women aged 38 or above show smaller productivity on their farms in comparison to younger women. Lastly, women who are also household heads show a larger and significantly negative effect on their productivity in comparison to women who are not household heads.[10] However, none of these differences are statistically significant. To that extent, there is not much heterogeneity in the gender gap in farm productivity, with regard to the household characteristics.

5.2. Profits

As discussed earlier, a better measure of farm efficiency is profitability since farms with lower yields could also have poor soil quality. A farm manager is likely to consider this while making production and input decisions. The farmer maybe doing the best in terms of productivity given the profits are maximized. Table 7 shows the results for profits generated by a farm household when village fixed effects and crop choice is controlled for. It can be seen that on an average, women earn 11% lower profits on their land for the same cultivated area and this negative effect increases to 13% when village effects are added as controls (Table 7, specification

[8] We first create an assets index (Filmer & Pritchett, 2001) and then compute deciles of this index. These deciles are created for all households in rural areas.

[9] These figures are obtained by dividing the reduction in coefficients after controlling for these variables by the initial gap of 11%.

[10] A further heterogeneous effect by *de facto* headship and *de jure* headship is conducted but the results are omitted for brevity. There is no significant difference between these two types of households.

Table 2
Difference between households by gender of farm manager: Input Usage.

Variable	Definition	Men (N = 13,105)	Women (N = 971)	Difference	
Irrigation	Proportion area cropped which is irrigated	0.469	0.403	−0.066	***
Household adult male labor	Mandays of household adult male labor per acre	88.793	49.109	−39.68	***
Household adult female labor	Mandays of household adult female labor per acre	47.399	147.477	100.08	*
Household child labor (10–14)	Mandays of household child labor per acre	1.958	4.421	2.463	**
Hired labor	Mandays of labor hired per acre	13.079	20.629	7.55	
Fertilizer	Percentage households who purchased fertilizer/manure	0.893	0.835	−0.058	***
Pesticide	Percentage households who purchased pesticide	0.536	0.398	−0.138	***
Hired Equipment	Percentage households who hire any tractors/equipments/animals for working on farm	0.635	0.653	0.018	
Irrigation water purchase	Percentage households who purchased irrigation water	0.284	0.254	−0.029	*
Credit	Percentage households who repaid some agricultural loan last year	0.084	0.035	−0.049	***
Own Tube-well	Percentage households who own tube well	0.182	0.108	−0.074	***
Own Electric Pump	Percentage households who own electric pump	0.164	0.113	−0.051	***
Own Diesel Pump	Percentage households who own diesel pump	0.107	0.054	−0.053	***
Own Bullock Cart	Percentage households who own bullock cart	0.162	0.06	−0.102	***
Own Tractor	Percentage households who own tractor	0.052	0.028	−0.024	***

Note: The sample includes all households which report a positive value of production in the last year. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.
Source: Author's calculations, IHDS I (2004).

Table 3
Difference between households by gender of farm manager: Demographic Characteristics.

Variable	Definition	Men (N = 13,105)	Women (971)	Difference	
Age	Age of farm manager	46.931	47.268	0.337	
Education	Number of years of education of farm manager	4.914	2.179	−2.735	***
Marital Status	Proportion Unmarried	0.023	0.027	0.004	
	Proportion Currently Married	0.937	0.287	−0.65	***
	Proportion with spouse not living in house	0.001	0.133	0.132	***
	Proportion widowed	0.036	0.537	0.501	***
	Proportion separated/Divorced	0.003	0.016	0.014	***
Asset Deciles	Decile 1 for assets score	0.076	0.064	−0.012	
	Decile 2 for assets score	0.089	0.104	0.016	
	Decile 3 for assets score	0.091	0.088	−0.002	
	Decile 4 for assets score	0.098	0.077	−0.021	**
	Decile 5 for assets score	0.101	0.092	−0.01	
	Decile 6 for assets score	0.1	0.071	−0.029	***
	Decile 7 for assets score	0.097	0.089	−0.007	
	Decile 8 for assets score	0.103	0.108	0.005	
	Decile 9 for assets score	0.108	0.135	0.028	**
	Decile 10 for assets score	0.138	0.171	0.032	***
Adult males	Number of adult males in household	1.833	1.164	−0.669	***

Note: The sample includes all households which report a positive value of production in the last year. The number of observations may differ for each variable if a particular question used to generate it has missing data. This is especially true for asset deciles since a few households do not report owned assets. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.
Source: Author's calculations, IHDS I (2004).

2). A large part of lower profits received by households where farms are managed by a woman is explained by crop choice since this negative gap reduces to 10% when controls for crop choice are included (Table 7, specification 3). When further controls for characteristics of the farm manager, household demographics and inputs are added in Table 8, the magnitude of the negative difference does not change much. It remains around 8% but it becomes insignificant (Table 8, specification 3). The main contributor to explaining the gender gap in profits is crop choice at 30% and the remainder is mostly unexplained. The results with respect to heterogeneity are not presented for brevity as they are not statistically significant.

6. Semi-parametric decomposition, robustness and mechanisms

6.1. Semi-parametric decomposition

The above results show that on an average, there exists a gender gap in value of output and profits. These results persist even after all controls are included in the regression. However, one cannot infer the part of the distribution where these gender differences in agricultural productivity are the largest, after inclusion of all controls, from the above regression analyses. In this section, we use the method proposed by DiNardo, Fortin and Lemieux (1996) (referred to as DFL from now onwards) to look at gender differences in productivity along the entire productivity distribution.

The main objective of a semi-parametric decomposition elucidated in DFL is to construct a counterfactual density of productivity that would prevail for households where men manage farms if they had the same location, individual and household characteristics as households where women manage farms. This method is a generalization of the Blinder-Oaxaca decomposition method.[11] To implement this method, we construct a counterfactual density plot it against the actual productivity density in households where women manage farms. The difference between the two densities then shows

[11] Blinder (1973) and Oaxaca (1973) developed this technique to decompose the gender wage gaps.

Table 4
Production Value: Difference between households by gender of farm manager (Village and crop controls).

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.114***	(0.036)	−0.105***	(0.027)	−0.077***	(0.026)
ln (Area)	−0.134***	(0.010)	−0.045***	(0.009)	−0.061***	(0.009)
Cereal					−0.366**	(0.180)
Pulses					−0.497***	(0.186)
Oilseeds					0.001	(0.187)
Spice					0.888***	(0.244)
Fruits & Veggies					0.947***	(0.193)
Non-food					0.591***	(0.197)
Other Controls						
Village Fixed Effects	No		Yes		Yes	
Crop Composition	No		No		Yes	
Characteristics FM	No		No		No	
Demographics HH	No		No		No	
Inputs	No		No		No	
Observations	14,076		14,076		14,076	
R-Square	0.022		0.577		0.614	

Note: The dependent variable is defined as the log of value of production per acre. The sample includes all households which report a positive value of production in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table 5
Production Value: Difference between households by gender of farm manager (All controls).

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.036	(0.032)	−0.087**	(0.034)	−0.073**	(0.032)
ln (Area)	−0.078***	(0.009)	−0.130***	(0.011)	−0.182***	(0.011)
Cereal	−0.346*	(0.178)	−0.346*	(0.183)	−0.354**	(0.180)
Pulses	−0.488***	(0.183)	−0.502***	(0.188)	−0.388**	(0.186)
Oilseeds	0.011	(0.185)	0.027	(0.192)	0.034	(0.188)
Spice	0.894***	(0.240)	0.823***	(0.246)	0.686***	(0.238)
Fruits & Veggies	0.937***	(0.191)	0.837***	(0.196)	0.722***	(0.193)
Non-food	0.600***	(0.194)	0.679***	(0.203)	0.611***	(0.199)
Age	0.002***	(0.001)	0.001	(0.001)	0.001**	(0.001)
Education	0.017***	(0.002)	0.008***	(0.002)	0.007***	(0.002)
Married	0.079*	(0.042)	0.067	(0.045)	0.057	(0.043)
Spouse migrated	0.069	(0.075)	0.036	(0.080)	0.005	(0.078)
Widowed	0.094*	(0.052)	0.116**	(0.055)	0.091*	(0.053)
Separated/Divorced	0.024	(0.116)	−0.048	(0.098)	−0.004	(0.089)
Irrigation					0.288***	(0.027)
Other Controls						
Village Fixed Effects	Yes		Yes		Yes	
Crop Composition	Yes		Yes		Yes	
Characteristics FM	Yes		Yes		Yes	
Demographics HH	No		Yes		Yes	
Inputs	No		No		Yes	
Observations	14,007		12,314		12,314	
R-Square	0.619		0.636		0.663	

Note: The dependent variable is defined as the log of value of production per acre. The sample includes all households which report a positive value of production in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

the productivity gap which remains unexplained even after all the observed differences in characteristics between the two types of farm managers are accounted for.

We briefly describe the method for constructing the counterfactual density below. In terms of notation, the actual density functions for productivity on men and women managed farms are written as:

$$f(y|G=M) = \int g(y|x, G=M)h(x|G=M)dx$$

$$f(y|G=F) = \int g(y|x, G=F)h(x|G=F)dx$$

Here G is the gender of the farm manager and $g(y|x, G=F)$ refers to density of productivity evaluated at productivity level 'y' when the characteristics of the individual farmer are given by 'x' and gender of the farm manager is 'Female'. Intuitively, it is a function that translates attributes to productivity. $h(x|G=F)$ refers to the density of attributes 'x' when farm manager is a female. In a parametric Blinder-Oaxaca decomposition, $h(x|G=M)$ is analogous to endowments, $g(y|x, G=F)$ would be returns to those endowments and $f(y|G=F)$ would be the average productivity of women farm managers. The counterfactual that we want to construct is density of productivity that would prevail for households where men manage farms if they had the same characteristics as households where women manage farms.[12] This is given by:

[12] It is possible to construct other counterfactual, for example what would have been the density of productivity measures for women if they had the same characteristics as men $= f_c^F(y) = \int g(y|x, G=F)h(x|G=M)dx$.

Table 6
Production Value: Difference between households by gender of farm manager (Heterogeneous effects, All Controls).

	Area Cultivated		Age		HH Head	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.094**	(0.039)	−0.045	(0.120)	−0.053	(0.063)
ln(Area)	−0.185***	(0.011)	−0.182***	(0.011)	−0.181***	(0.011)
Woman FM*ln(Area)	0.041	(0.030)				
Age	0.001**	(0.001)	0.001**	(0.001)	0.001**	(0.001)
Woman FM*Age			−0.001	(0.002)		
HH Head					0.012	(0.026)
Woman FM*HH Head					−0.029	(0.076)
Null: Woman FM + Woman FM*Area = 0	Reject below 3 acre					
Null: Woman FM + Woman FM*Age = 0			Reject at age 38 & above			
Null: Woman FM + Woman FM*HH Head = 0					Reject	
Other Controls						
Village Fixed Effects	Yes		Yes		Yes	
Crop Composition	Yes		Yes		Yes	
Characteristics FM	Yes		Yes		Yes	
Demographics HH	Yes		Yes		Yes	
Inputs	Yes		Yes		Yes	
Observations	12,314		12,314		12,314	
R-Square	0.663		0.663		0.663	

Note: The dependent variable is defined as the log of value of production per acre. The sample includes all households which report a positive value of production in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table 7
Profit: Difference between households by gender of farm manager (Village and crop controls).

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.107**	(0.050)	−0.132***	(0.041)	−0.098**	(0.040)
ln (Area)	−0.125***	(0.012)	−0.013	(0.013)	−0.033***	(0.012)
Cereal					−0.534*	(0.291)
Pulses					−0.505*	(0.298)
Oilseeds					−0.066	(0.302)
Spice					1.121***	(0.360)
Fruits & Veggies					0.955***	(0.306)
Non-food					0.708**	(0.311)
Other Controls						
Village Fixed Effects	No		Yes		Yes	
Crop Composition	No		No		Yes	
Characteristics FM	No		No		No	
Demographics HH	No		No		No	
Inputs	No		No		No	
Observations	12,059		12,059		12,059	
R-Square	0.013		0.488		0.519	

Note: The dependent variable is defined as the log of value of profits per acre. The sample includes all households which report a positive value of profit in the last year. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

$$
\begin{aligned}
f_c^M(y) &= \int g(y|x,\ G=M)h(x|G=F)dx \\
&= \int g(y|x,\ G=M)h(x|G=M)\frac{h(x|G=F)}{h(x|G=M)}dx \\
&= \int g(y|x,\ G=M)h(x|G=M)\varphi(x)dx
\end{aligned}
$$

The above counterfactual can be constructed by using the below identity given by Bayes' Theorem:

$$\frac{h(x|G=F)}{h(x|G=M)} = \frac{\Pr(G=F|X=x)}{(1-\Pr(G=F|X=x))}\frac{\Pr(G=M)}{\Pr(G=F)}$$

In the above expression $\varphi(x)$ is also called a re-weighting function. The counterfactual can be computed using a weighted density estimate of productivities for households where men manage farms. The weights are given by $\varphi(x)$. This re-weighting function can be obtained by using predicted probabilities from a logit model which predicts the probability that a particular observation belongs to a household where a woman manages the farm on the basis of observed characteristics (X) from pooled observations. This gives an estimate for $\Pr(G=F|X=x)$. An estimate for $\Pr(G=M)$ can be obtained by computing the proportion of farm households where men manage farms.

Fig. 1 shows the kernel density plots for production value in households where women manage farms and the counterfactual distribution for production value in households where men manage farms (after controlling for area, crop choice, demographics, location and inputs). It can be clearly seen that even if men managed farm households had the same characteristics as women managed farm households, they would still have larger output values. This difference is starker at the lower to middle level of the production value distribution. Hence, differences in observables cannot completely explain the lower output value obtained in households where women manage farms, at the lower end of the productivity distribution. The actual distribution of profits for women managed farm households and the counterfactual distribution for men managed farm households is shown in Fig. 2. Here, the differences between the two distributions are less stark. We

Table 8
Profit: Difference between households by gender of farm manager (All controls).

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.080*	(0.048)	−0.082	(0.050)	−0.079	(0.050)
ln (Area)	−0.041***	(0.013)	−0.074***	(0.015)	−0.102***	(0.016)
Cereal	−0.520*	(0.293)	−0.544*	(0.312)	−0.526*	(0.319)
Pulses	−0.509*	(0.299)	−0.576*	(0.318)	−0.458	(0.326)
Oilseeds	−0.060	(0.303)	−0.089	(0.325)	−0.033	(0.330)
Spice	1.134***	(0.360)	1.025***	(0.381)	0.916**	(0.383)
Fruits & Veggies	0.955***	(0.308)	0.834**	(0.328)	0.744**	(0.334)
Non-food	0.714**	(0.312)	0.775**	(0.334)	0.762**	(0.340)
Age	0.001	(0.001)	0.000	(0.001)	0.000	(0.001)
Education	0.007***	(0.002)	0.003	(0.003)	0.003	(0.003)
Married	0.058	(0.063)	0.050	(0.066)	0.040	(0.066)
Spouse migrated	−0.019	(0.116)	−0.046	(0.124)	−0.055	(0.123)
Widowed	0.077	(0.076)	0.072	(0.080)	0.047	(0.080)
Separated/Divorced	−0.034	(0.169)	−0.071	(0.152)	−0.044	(0.152)
Irrigation					0.323***	(0.040)
Other Controls						
Village Fixed Effects	Yes		Yes		Yes	
Crop Composition	Yes		Yes		Yes	
Characteristics FM	Yes		Yes		Yes	
Demographics HH	No		Yes		Yes	
Inputs	No		No		Yes	
Observations	11,998		10,609		10,609	
R-Square	0.521		0.534		0.548	

Note: The dependent variable is defined as the log of value of profits per acre. The sample includes all households which report a positive value of profit in the last year. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

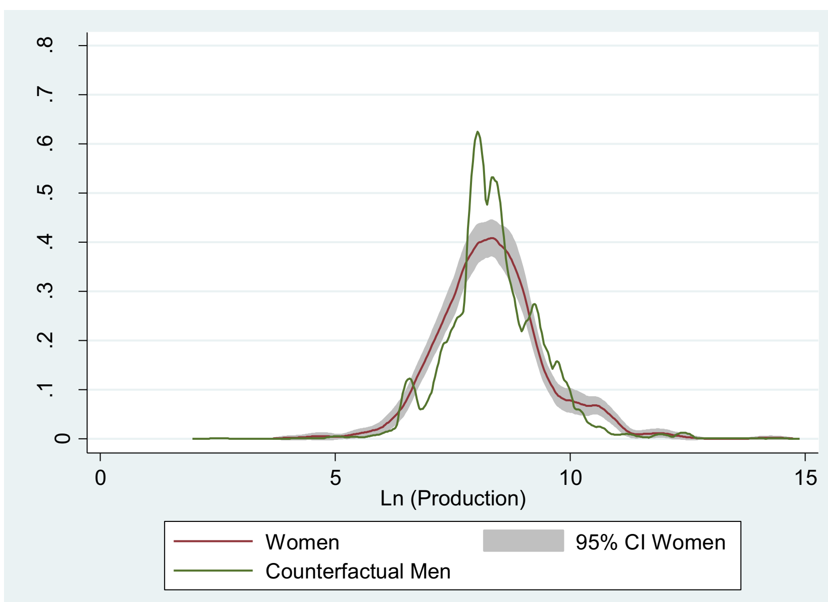

Fig. 1. Production value: Actual distribution for women farm managers and counterfactual distribution for men farm managers.
Note: The sample includes all households which report a positive value of production in the last year.

observe a significant difference only at lower and middle value of profit distribution.

These figures constructed using semi-parametric density estimation corroborate the results of Section 5 where gender gaps were observed at the mean of the productivity distribution, even after all controls were added. Additionally, this analysis shows that women at lower end of the production and the profit value distributions have lower productivity measures than men. At higher value of the productivity distributions, there is no significant gender gap in productivities once all the controls have been included.

6.2. Robustness

The results presented above hinge on exogeneity of the gender of the farm manager, conditional on the controls included. An important omitted control in our analyses is soil quality of plots operated by a household.[13] This could have been overcome by hav-

[13] Studies for other countries which control for farm characteristics like elevation, soil degradation, slope do not find any significant changes in their results when these factors are controlled for (Kilic et al. (2015) for Malawi, De la O Campos et al. (2016) for Uganda, Aguilar et al. (2015) for Ethiopia, Oseni et al. (2015) for Nigeria, Slavchevska (2015) for Tanzania).

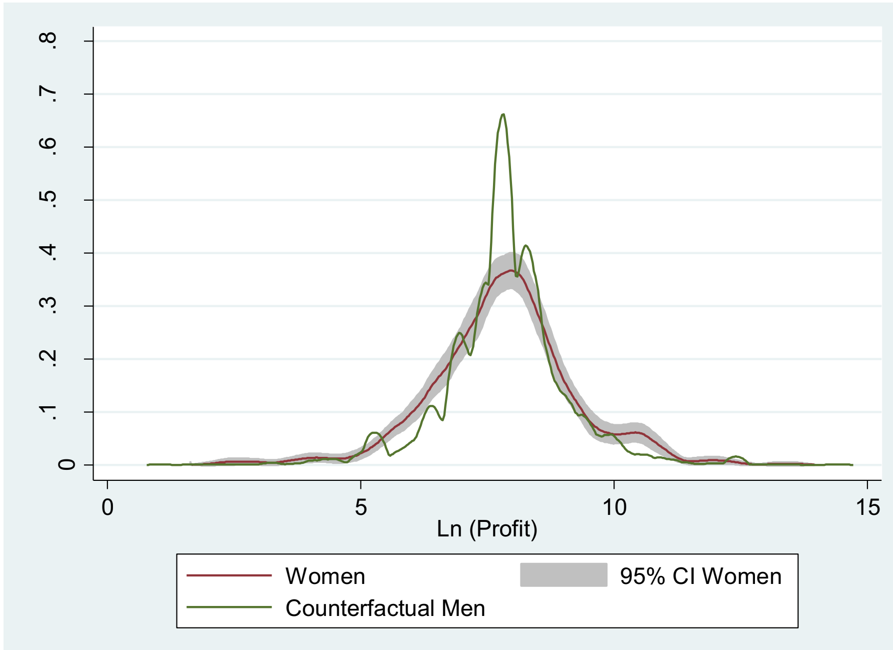

Fig. 2. Profit value: Actual distribution for women farm managers and counterfactual distribution for men farm managers.
Note: The sample includes all households which report a positive value of profits in the last year.

ing access to either soil quality data or panel data on plot level crop production across years which would allow for plot fixed effects. Slavchevska (2015) is one of the few studies in existing literature which uses panel data at household-plot level to analyze this question for Tanzania. It finds that adding household fixed effects further reduces the productivity value on female managed plots, in comparison to male managed plots, from 14% to almost 30%. Unfortunately, such a dataset is not available for India. Given data limitations, the selection bias can be best addressed by inclusion of comprehensive controls for plot location and household characteristics. This is addressed in the paper, primarily by inclusion of village fixed effects, since variability in soil quality and agricultural conditions across villages are primary drivers of differences in farm productivities in India.[14]

The defense of this estimation strategy rests on similarity in agro-ecological conditions and access to inputs within a village. The concern then is possible variation in soil quality across plots within a village being the main driver behind the obtained results. The question is, how likely is the claim that women manage farms within a village in households having poor quality land and this is driving the smaller productivities on women managed farms? Firstly, it must be noted that proportion of households where women manage farms due to spousal migration, are only 13% of our sample and those managing farms due to their husbands engaged in non-farm work are 28%. There are large differences in male migration patterns and access to non-farm work across villages, so it is likely that for a large part of our sample, village fixed effects would eliminate this selection bias. Within villages it is more likely that male migration and participation in non-farm work is more in households with small and unviable landholdings than due to poorer soil quality. We also control for proportion of irrigated farmland operated by a household which is a major predictor of farm productivity in India within a village.

Secondly, even if some selection bias is not eliminated after inclusion of village fixed effects, farm irrigation and household wealth controls, what is the direction of the likely bias arising from within village variation in land characteristics? This depends on the direction of correlation between the gender of the farm manager and soil quality within a village. Dubey, Palmer-Jones and Sen (2006) find that within labor surplus regions, it is the richer households and those with males having more education, who are more likely to migrate. Similarly, existing literature shows that more educated men residing in wealthier households are more likely to work in the non-farm sector within a village (Lanjouw & Shariff, 2004). Wealthier households are also likely to have lands of better soil quality and women then should be managing farms in these households.[15]

However, it is also plausible that migration and non-farm work by male household members is distress driven within a village and women are more likely to manage farms in households having poor quality land. We are more concerned about the case when women operate low quality land. In this case there is a possibility that if we had controls for soil quality, then there would be no differential productivities across households where women and men manage farms.[16] In the absence of farm level panel data, the next best alternative is an assessment of the omitted variable bias due to such unobservable factors in the model. We follow a strategy developed by Altonji, Elder and Taber (2005) and Oster (2017). This is based on the idea that selection on observables can be useful to

[14] Inclusion of village fixed effects explains approximately 60% of the variation farm productivities in IHDS (R-Square in Table 5).

[15] This is also substantiated by the fact that addition of household demographics like caste and asset ownership, accentuates the lower productivities on women managed farm households (Table 5).

[16] In general, sign of the omitted variable bias can be determined by multiplying the effect of unobserved variables (soil quality) on farm productivity and correlation of female farm management with soil quality within a village (Wooldridge, 2010). The former is positive and the latter can be positive or negative, depending on whether women operate superior quality land or inferior quality land within a village. When women operate low (high) quality land within a village in India then the estimates in this paper will be an overestimate (underestimate) of the true lower productivity on women managed farms.

assess the selection based on un-observables. Consider the below regression equation

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + Z + u$$

where X_1 is the main variable of interest, X_2 is observed and Z contains all the unobserved variables. The objective is to estimate the bias on β_1 because of Z. Altonji, Elder and Taber (2005) estimate this bias by assuming:

$$\frac{Cov(X_1, Z)}{Var(X_2)} = \delta \frac{Cov(X_1, \beta_2 X_2)}{Var(\beta_2 X_2)}$$

Here δ gives the degree of proportionality that relates selection on un-observables (relation between X_1 and Z) with selection on observables (relation between X_1 and X_2). Oster (2017) extends this idea to estimation of possible bias by looking at the coefficient movements (β_1) along with changes in R-Square when observable covariates are added. It is possible to derive a consistent estimator for the effect of gender on farm productivity using this method. We need two parameters for this: δ (degree of proportionality) and R_{Max} (R-square of a hypothetical regression which includes all the unobserved variables). To implement the above method, we first need a baseline regression to which subsequent controls would be added. We posit a baseline regression where log of value of production is regressed on area cultivated and gender of the farm manager.

Second, we need a value for R_{Max}. This can be obtained by looking at existing studies which include controls for soil quality. Kilic, Palacios-Lopez and Goldstein (2015) for Malawi, De la O Campos et al. (2016) for Uganda, Aguilar et al. (2015) for Ethiopia and Oseni et al. (2015) for Nigeria use various controls for soil quality and have a range of R-square from 0.33 to 0.426. Table 5 shows that the R-Square in this paper without soil quality controls, is much higher than that in existing cross-sectional studies. In fact, R-Square in this paper (0.66) is closer to R-Square of 0.80 in Slavchevska (2015), which uses panel data to analyze the same question for Tanzania, including controls for household and plot-crop fixed effects. The other method to get a value of R_{Max} suggested in Oster (2017) is to set it at 1.3 times the R-square in the model with full controls. In our case this turns out to 0.86, higher than the largest R-square in the existing literature. To be on the conservative side, we take $R_{Max} = 0.86$.

The last thing required is a value for δ. This is based on our understanding of how important we think selection on un-observables is as compared to selection on observables. For our purposes, it is quite clear, that with village fixed effects and an already high R-Square obtained, this value can be safely taken to be less than one i.e. selection on un-observables is less in comparison to selection on observables. The average value of δ in Oster (2017) was 0.54. Nevertheless, we assess the coefficient on woman farm manager for a range of $\delta \in (0, 1]$.

Table 9 shows the results for the above analyses. It can be seen that even after correcting for the bias when $\delta = 1$, gender gap in production value is 3% and profit value is 3.8%. The standard errors increase and the coefficient become insignificant but the sign does not reverse for these plausible but extremely conservative assumptions on baseline regression, δ and R_{Max}. With an initial baseline regression where log of value of production is regressed only on the gender of the farm manager, the above analysis shows a positive bias. Removing this bias then reduces the production value by 14% (when $\delta = 1$) in households where women manage farms in comparison to those where men manage farms. This is larger than the 7% effect obtained in Table 5. The results have been omitted for brevity but are available on request.

6.3. Mechanisms

The results obtained show that both productivity and profits are lower on women managed farms. There are two important factors which act as mediators in our analyses - the crop choice and the input usage by the farm household – which explains approximately 45% of the gender productivity gap. Women tend to cultivate more cereals and food crops than non-food crops which leads to a lower value of production on same farm size (Table 1). Also, lower usage of inputs like irrigation, credit, fertilizers, pesticides and other machine equipment on women managed farms leads to lower productivity obtained for the same crop (Table 2). One reason for lower input usage could be lack of purchasing capacity for these inputs in households where women manage farmlands. Second, it could also be due to limited knowledge about best cultivation practices among women farm managers or because they are not able to bargain for purchase of these inputs among various competing uses of their limited resources. The first reason seems less likely because households where women manage farms and those where men manage farms are similar in wealth (Table 3).

Notably, the comprehensive set of controls in our analyses, cannot completely explain the differences in productivity by gender. Farm households where women manage farms have 7% lower production and profits even after controls for location, crop composition, inputs and other demographic characteristics are included. The next question that immediately arises is what other mechanisms can potentially explain this residual difference. In studies where a substantial residual remains (as in our case), the question which remains unanswered is whether the residual is due to managerial ability, varying by gender of the farm manager or due to other omitted variables like soil quality. While we cannot explicitly test for soil quality, the Indian context allows us to throw some light on the first mechanism of lack of adequate knowledge among women farm operators.

We cannot directly measure experience or training levels of the farm managers in our study but the Indian context is helpful due to existing evidence on gender roles across crops. It has been well documented in the agriculture literature that rice cultivation involves greater demand for women's labor (Boserup, 1970). Studies have also shown that historically in India women's involvement has been greater in rice cultivation. Agricultural tasks like transplanting and weeding are predominantly performed by women in rice growing areas. Wheat has traditionally involved more male labor due to ploughing and sowing being the main agricultural tasks in wheat cultivation (Bardhan, 1974).

Equipped with this evidence, studies have compared female labor force participation rates in agriculture across rice and wheat growing regions (Agarwal, 1986; Chen, 1989; Mbiti, 2007; Chin, 2011; Mahajan, 2017). They find that regions where rice cultivation was intensive, involvement of women in agriculture activities was greater and still persists. If involvement of women has been historically greater in rice cultivation then one would expect that they are likely to have more experience and knowledge about the best cultivation practices for rice. Crop specific differences in agriculture productivity can then throw some light on whether experience, which is acquired through involvement in production processes, is one of the channels through gender gap in productivity plays out, even after all controls are included.[17]

[17] A direct test of the hypothesis could have been a measure of women's experience in cultivation. However, the data does not capture any such measure. An indirect construction of the measure through husband's death or the year of migration is also not captured in the data. We can only identify whether the husband is a migrant currently or the woman is a widow.

Table 9
Robustness: Difference between households by gender of farm manager.

$\delta =$	1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
	Panel A: Value of Output (R_{Max} = 0.86)									
Woman FM	−0.028	−0.034	−0.04	−0.045	−0.05	−0.054	−0.058#	−0.062*	−0.066*	−0.069**
	(0.053)	(0.051)	(0.047)	(0.046)	(0.041)	(0.04)	(0.04)	(0.037)	(0.035)	(0.035)
	Panel B: Value of Profit (R_{Max} = 0.71)									
Woman FM	−0.038	−0.044	−0.049	−0.054	−0.058	−0.062	−0.066	−0.07	−0.073	−0.076#
	(0.074)	(0.066)	(0.066)	(0.061)	(0.056)	(0.059)	(0.055)	(0.055)	(0.053)	(0.051)

Note: The dependent variable is defined as the log of value of production per acre in Panel A. The dependent variable is defined as the log of value of profits per acre in Panel B. The sample includes all households which report a positive value of production in Panel A and those which report a positive value of profit in the last year in Panel B. Bootstrapped standard errors in parentheses. ***, **, * and # indicate significance at the 1%, 5%, 10% and 15% levels respectively.

We estimate the main specification with the dependent variable as crop specific yields. As mentioned above, the two crops considered here are rice and wheat since gender roles across these two crops are distinct. These are also predominant cereals in India covering more than 50% of total area under cultivation. Table 10 shows the results for rice yield and Table 11 shows the results for wheat yield. The crop yields are measured at plot level. Women managed plots which cultivate rice show a lower yield by 7% in comparison to male managed plots. This becomes small and insignificant when controls for manager characteristics and inputs are added. On the other hand, wheat yields are lower by 13% on women managed plots and this difference does not reduce when other controls are included. These results are in line with the hypothesis that women have more experience due to their historical involvement in rice cultivation in India. Insufficient involvement in crop cultivation prior to taking up management, as in the case of wheat crop, can be one of the channels through which the residual productivity gap between men and women plays out.

The channel of inadequate knowledge and experience driving the residual productivity gap can also be corroborated by using variation across regions in gender norms in India. The north-south divide in gender equity in India has been a focal point of many studies which find that women have less autonomy in north (Dyson and Moorem 1983; Basum 1992; Jejeebhoym 2000). The pattern of lower female workforce participation rates in north India relative to south India and its persistence over many decades has been well noted (Boserup, 1970; Chen, 1995; Mahajan and Ramaswami, 2017). Taking a cue from these studies, we see if there is heterogeneity in productivity effects across the northern and southern regions of India.[18] There is no difference in proportion of households where women manage farms across the north and the south and is approximately equal to the country average of 8%.

The estimation results are presented in Table 12 for the northern states and in Table 13 for the southern states of India. After inclusion of all controls, there is no differences in productivity levels in south across households where men and women manage farms. Without controls, there exists a gender productivity gap of 7% when households operate farms of same size in south but differences in crop composition explain this gap and we observe no gender gap in Table 13. However, in the north, even after inclusion of all controls, the gender productivity gap in production value is 10% and profit value is 9%. This is large and significant.

These results have policy implications. If managerial ability across gender differs due to inexperience, lack of access to training and information then provision of extension services to women farm operators can be useful. Agarwal (2003) using primary data on group-based women farmers in India finds two main constraints faced by them – credit and cash to purchase inputs and gender biases in extension services. These extension service programs need to have a special component which explicitly caters to the needs of women farm operators. There exists an economic rationale behind such targeting because returns to these efforts are likely to be greater for women managers. An increase in productivity on women managed farms will lead to an overall increase in agricultural production as well as an increase in income generation for women. Alongside with extension, greater access to credit must be provided on more favorable terms to help women farm operators purchase agricultural inputs which they are otherwise not able to use on their land. The above analysis also suggests that cultural barriers in access to these services, rooted in pre-existing gender norms, will also have to be taken into account. There is a greater need for these programs in the northern states where women have traditionally been excluded from agricultural work.

Can there be other possible mechanisms apart from lack of experience among women farm managers? We discuss three more possibilities for the residual difference here. First, there is a possibility that differential prices are received by women and men for their agricultural produce. This is because prices received for the same crop can differ across farm households due to discrimination or differences in bargaining power in the sale market. Both can be a function of gender of the farm manager. Our main variable of interest, consistent with the existing literature, is value of production per acre. In general, it is not possible to aggregate yields across crops since they are measured in different units.

The literature circumvents this problem by either using the value of output. This is obtained by multiplying the output for each crop with the price received for that crop and aggregated over all the crops cultivated by the household and divided by total area cultivated under those crops. To see whether this possible alternative mechanism is behind the lower production values obtained for women farm managers, we regress prices for two major crops – rice and wheat – on gender of the farm manager and other characteristics. This is done at the plot level and the results are given in Tables A1 and A2 in Appendix. It can be seen that if anything women are able to get a better bargain in terms of price for their produce. This is true for both rice and wheat. Thus, lower production values on women managed farms in India, are due to lower farm productivities and not lower price received for produce, in comparison to men managed farms.

Second, there is a possibility that differences in farm productivities are driven by women farm managers, who are more time constrained or physically infirm, rather than inexperienced. This is because most of the women farm managers in our sample are either widowed or have husbands who have migrated to the city. To see whether this possible alternative mechanism is behind the lower production values obtained for women farm managers, we restrict the sample to only those women and men who are currently married and cohabit. The results are given in Table A3 in Appendix. It can be seen that even in households where farm is

[18] In the existing literature, Southern India is defined to include Deccan and regions to the south of Deccan. We classify Andhra Pradesh, Karnataka, Kerala, Maharashtra, and Tamil Nadu as southern states, while Punjab, Haryana, Uttar Pradesh, Assam, Bihar, Gujarat, Rajasthan, Madhya Pradesh, Orissa and West Bengal are classified as northern states.

Table 10
Rice Yield: Differences across men and women managed farms.

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.076***	(0.028)	−0.038	(0.034)	−0.051	(0.035)
ln (Area)	−0.122***	(0.011)	−0.136***	(0.011)	−0.189***	(0.013)
Irrigated plot			0.141***	(0.021)	0.122***	(0.023)
Age			0.001**	(0.001)	0.000	(0.001)
Education			0.013***	(0.002)	0.007***	(0.002)
Other Controls						
Season	Yes		Yes		Yes	
Village Fixed Effects	Yes		Yes		Yes	
Characteristics FM	No		Yes		Yes	
Demographics HH	No		No		Yes	
Inputs	No		No		Yes	
Observations	8,241		8,200		7,584	
R-Square	0.645		0.653		0.673	

Note: The sample includes all plots on which a household reports rice cultivation in the last year. The controls for season include indicator variables for whether the crop was cultivated in Kharif, Rabi or Summer season. Input controls include all the input controls in Table 2 except measures of labor used on land since these are likely to suffer from measurement error, as they are not crop specific. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table 11
Wheat Yield: Differences across men and women managed farms.

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.133***	(0.033)	−0.130***	(0.044)	−0.149***	(0.044)
ln (Area)	−0.107***	(0.011)	−0.122***	(0.012)	−0.191***	(0.014)
Irrigated plot			0.234***	(0.040)	0.189***	(0.041)
Age			0.001	(0.001)	−0.001	(0.001)
Education			0.010***	(0.002)	0.003	(0.002)
Other Controls						
Season	Yes		Yes		Yes	
Village Fixed Effects	Yes		Yes		Yes	
Characteristics FM	No		Yes		Yes	
Demographics HH	No		No		Yes	
Inputs	No		No		Yes	
Observations	6,253		6,223		5,618	
R-Square	0.587		0.592		0.624	

Note: The sample includes all plots on which a household reports wheat cultivation in the last year. The controls for season include indicator variables for whether the crop was cultivated in Kharif, Rabi or Summer season. Input controls include all the input controls in Table 2 except measures of labor used on land since these are likely to suffer from measurement error, as they are not crop specific. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

managed by a woman, who is unlikely to be physically infirm due to old age or time constrained because of husband's migration, obtain lower value of farm production by 8.8% after all the controls are included. This possible mechanism then cannot be the main reason behind the residual gender productivity gap in productivity. A similar exercise was carried out to check if presence of small children in the household can be a source of time constraint for women farm operators who need to manage domestic work and the fields. Appendix Table A4 shows the regression estimates including small children and their interaction with gender of the farm manager. No significant effects are seen.

Third, there can be differences in recall by men and women driving the residual gender productivity gap, since data is collected on a recall basis for last agricultural year. Data on agricultural production, prices and costs is collected from the most knowledgeable person about farm matter decisions (the farm manager) or if this person is unavailable then the household head. If women farm managers on an average underestimate revenues or overestimate costs then the results could possibly be driven by that. Unfortunately, there are no studies which directly measure recall bias in Indian agriculture. There are two recent experimental papers by Arthi et al. (2018) and Gaddis et al. (2019) for Tanzania and Ghana respectively which evaluate recall bias in household farm labor measurement. These come closest to a developing country context where small holder agriculture is extensive.

Arthi et al. (2018) find a substantial recall bias when farm labor is measured at the end of the season as compared to when it is measured on a weekly basis. This leads to an underestimation of agricultural labor productivity. However, there are no differences in the recall bias by the gender of respondent. Gaddis et al. (2019) using a similar experimental strategy detect small biases in recall data for Ghana, and find insignificant difference in the recall bias across gender. We find no support in the existing literature for differential recall bias by gender in labor inputs on farm. Lastly, differential health status between men and women could also be a potential driver of the residual gap. IHDS survey records anthropometric measures but it is mandatory only for children and one eligible woman in a household. In our sample of farm managers this data is recorded for 5% of them, making it unsuitable for analyses. National Family Health Survey-3 shows that on an average 41% women have lower nutrition as compared to 38% men in rural areas. A study by Jose (2011) finds that gender gap in anaemia prevalence is larger than energy deficiency but there is no systematic variation in the gap between north and south. Our earlier analysis shows that negative and significant effects exist only for northern states. This somewhat alleviates the concern that health status is an omitted variable driving the gender productivity gap. But future studies must collect information on health status of farmers to fully address this possibility.

Table 12
Production and Profits: Difference between households by gender of farm manager in North India (All Controls).

	(1) Production		(2) Profit	
Variable	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.103***	(0.033)	−0.093*	(0.052)
ln (Area)	−0.122***	(0.012)	−0.062***	(0.018)
Age	0.000	(0.001)	−0.001	(0.001)
Education	0.004**	(0.002)	0.001	(0.003)
Irrigation	0.294***	(0.028)	0.306***	(0.044)
Other Controls				
Village Fixed Effects	Yes		Yes	
Crop Composition	Yes		Yes	
Characteristics FM	Yes		Yes	
Demographics HH	Yes		Yes	
Inputs	Yes		Yes	
Observations	9290		8251	
R-Square	0.653		0.5	

Note: The dependent variable is defined as the log of value of production per acre in column (1) and the sample includes all households which report a positive value of production in the last year. The dependent variable is defined as the log of value of profits per acre in column (2) and the sample includes all households which report a positive value of profits in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table 13
Production and Profits: Difference between households by gender of farm manager in South India (All Controls).

	(1) Production		(2) Profit	
Variable	Coeff	S.E.	Coeff	S.E.
Woman FM	0.000	(0.093)	−0.005	(0.155)
ln (Area)	−0.288***	(0.029)	−0.124***	(0.045)
Age	0.005***	(0.002)	0.004	(0.002)
Education	0.018***	(0.005)	0.007	(0.008)
Irrigation	0.269***	(0.067)	0.408***	(0.101)
Other Controls				
Village Fixed Effects	Yes		Yes	
Crop Composition	Yes		Yes	
Characteristics FM	Yes		Yes	
Demographics HH	Yes		Yes	
Inputs	Yes		Yes	
Observations	2780		2149	
R-Square	0.656		0.59	

Note: The dependent variable is defined as the log of value of production per acre in column (1) and the sample includes all households which report a positive value of production in the last year. The dependent variable is defined as the log of value of profits per acre in column (2) and the sample includes all households which report a positive value of profits in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

7. Conclusion

This paper looks at men and women farm managers in India and differences in their agricultural productivity. The results show that women have lower access to inputs like family labor, irrigation, fertilizers, own farm equipment and credit. Notably, women manage smaller farms and on an average the production value and the profits are lower on these farms by 11%, conditional on the cultivated area. The production value on women managed farms is lower than men managed farms by approximately 7% even after controls for crop composition, input usage, farm manager and household characteristics and location are included. Crop choice and lower input usage by the farm household explain approximately 45% of the initial gender productivity gap. The gender gap predominates along the lower to mid-level of productivity distributions and attenuates at the higher end once the controls are included.

We further shed some light on possible mechanisms driving the residual productivity gap of 7%, unexplained by the control variables included in the model. To infer this, the paper exploits existing evidence in literature on gender roles across crops in India. Women have been traditionally more involved in rice cultivation in India and wheat has been predominantly regarded as a male crop. We examine the yield differences across rice and wheat. The results show that there is little difference between men and women managed farms in rice productivity once season, location, inputs and farmer characteristics have been controlled for. However, wheat yields on women managed farms are lower by almost 15% even after all the controls are included. This evidence suggests lack of experience in wheat cultivation practices due to gendered roles, resulting in a residual gap. The mechanism of lack of adequate knowledge and experience, is further corroborated by looking at regional variation in gender productivity gaps. Northern region of India where women's autonomy has historically been low, shows 10% residual gap whereas, southern India shows no residual productivity gap. This evidence further strengthens the posited mechanism.

The results indicate that policy must ensure that extension services reach the women farmers in India, especially in areas where women have not been traditionally involved in agriculture. Women's role in farm management is increasing and improving crop productivity on these farms must be an active ingredient of agricultural policy making in India. Recent government initiatives like *Mahila Kisan Swashaktikaran Pariyojna (MKSP)*, started in 2010 and covering 20% of Indian districts, aim to build knowledge, skills and capacities of women farmers. These programs require to be strengthened and the extent of reach and scale of these programs needs to be increased for women farm operators to reap their full benefits through higher farm productivity.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Rice price: Differences across men and women managed farms.

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	0.019**	(0.008)	0.024**	(0.010)	0.024**	(0.010)
ln (Area)	0.001	(0.002)	0.001	(0.002)	−0.000	(0.003)
Irrigated plot			0.002	(0.006)	0.007	(0.007)
Age			−0.000	(0.000)	−0.000	(0.000)
Education			0.000	(0.000)	0.000	(0.001)
Other Controls						
Season	Yes		Yes		Yes	
Village Fixed Effects	Yes		Yes		Yes	
Characteristics FM	No		Yes		Yes	
Demographics HH	No		No		Yes	
Inputs	No		No		Yes	
Observations	8,241		8,200		7,584	
R-Square	0.774		0.776		0.778	

Note: The dependent variable is defined as the log of price per quintal obtained by the farmer for rice crop cultivated on a plot. The sample includes all plots on which a household reports rice cultivation in the last year. The controls for season include indicator variables for whether the crop was cultivated in Kharif, Rabi or Summer season. Input controls include all the input controls in Table 2 except measures of labour used on land since these are likely to suffer from measurement error as they are not crop specific. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table A2
Wheat price: Differences across men and women managed farms.

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	0.012***	(0.004)	0.013**	(0.005)	0.015***	(0.005)
ln (Area)	0.004***	(0.001)	0.004**	(0.001)	0.002	(0.002)
Irrigated plot			−0.006	(0.005)	−0.004	(0.006)
Age			0.000	(0.000)	0.000	(0.000)
Education			0.000	(0.000)	0.000	(0.000)
Other Controls						
Season	Yes		Yes		Yes	
Village Fixed Effects	Yes		Yes		Yes	
Characteristics FM	No		Yes		Yes	
Demographics HH	No		No		Yes	
Inputs	No		No		Yes	
Observations	6,253		6,223		5,618	
R-Square	0.713		0.715		0.705	

Note: The dependent variable is defined as the log of price per quintal obtained by the farmer for wheat crop cultivated on a plot. The sample includes all plots on which a household reports wheat cultivation in the last year. The controls for season include indicator variables for whether the crop was cultivated in Kharif, Rabi or Summer season. Input controls include all the input controls in Table 2 except measures of labour used on land since these are likely to suffer from measurement error as they are not crop specific. Robust standard errors in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table A3
Production Value: Difference between households by gender of farm manager (those currently married).

	(1)		(2)	
Variable	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.114**	(0.052)	−0.088*	(0.048)
ln (Area)	−0.127***	(0.011)	−0.168***	(0.012)
Age	0.001	(0.001)	0.001*	(0.001)
Education	0.008***	(0.002)	0.008***	(0.002)
Irrigation			0.290***	(0.029)
Other Controls				
Village Fixed Effects	Yes		Yes	
Crop Composition	Yes		Yes	
Characteristics FM	Yes		Yes	
Demographics HH	Yes		Yes	
Inputs	No		Yes	
Observations	10,970		10,970	
R-Square	0.643		0.67	

Note: The dependent variable is defined as the log of value of production per acre. The sample includes all households which report a positive value of production in the last year and where farm manager is currently married and cohabits with the spouse. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

Table A4
Production Value: Difference between households by gender of farm manager (Heterogeneous effects of small children in household).

	(1)		(2)		(3)	
Variable	Coeff	S.E.	Coeff	S.E.	Coeff	S.E.
Woman FM	−0.073**	(0.032)	−0.081**	(0.037)	−0.069*	(0.039)
ln(Area)	−0.182***	(0.011)	−0.182***	(0.011)	−0.182***	(0.011)
Children 0–5	0.003	(0.006)	0.002	(0.006)		
Woman FM*Children 0–5			0.014	(0.024)		
Children 0–5 (Dummy)					0.008	(0.013)
Woman FM*Children 0–5 (Dummy)					−0.011	(0.049)
Other Controls						
Village Fixed Effects	Yes		Yes		Yes	
Crop Composition	Yes		Yes		Yes	
Characteristics FM	Yes		Yes		Yes	
Demographics HH	Yes		Yes		Yes	
Inputs	Yes		Yes		Yes	
Observations	12,314		12,314		12,314	
R-Square	0.663		0.663		0.663	

Note: The dependent variable is defined as the log of value of production per acre. The sample includes all households which report a positive value of production in the last year. Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively.

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