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A Gender Gap in Agricultural Productivity?

Evidence from the Dairy Sector in India

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Abstract.

In agriculture, women have been found to be less productive than men for a variety of reasons. Most of the studies in this domain focus on crop production, and so far there has been little evidence on the impact of gender on productivity in dairy. This paper provides empirical evidence of the impact of female decision-making power on dairy productivity in India, based on a unique household-level dataset collected in 2010 in 50 villages in Andhra Pradesh, a state in the South of India. Our analysis suggests that higher productivity is achieved in households where women take dairy production-related decisions. While caution is due in drawing overly strong conclusions, our results provide a more nuanced view on the impact of gender on agricultural productivity than the one usually put forward in the literature.

Keywords: agricultural productivity, dairy sector, gender, female decision-making power

JEL codes: Q18, O13

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1. Introduction

The last two and a half decades witnessed great improvement in the absolute status of women and in gender equality across the globe. Yet, in many of these countries gender bias still constitutes a genuine challenge, with women lagging behind men in many dimensions: access to productive resources, education,[2] labor market opportunities, and legal rights and representation.[3]

Giving women equal access to opportunities and resources can contribute to aggregate growth by improving efficiency in the allocation of scarce resources (World Bank, 2011). In addition, female economic empowerment is sometimes considered as a "magic potion" for development (Blumberg, 2005), inspired by a growing empirical literature suggesting that many key development outcomes, such as improved child nutrition, health and education, depend on women's ability to negotiate favorable intra-household allocations of resources (Thomas, 1993; Bussolo et al., 2009; Quisumbing et al., 2002; Dercon and Krishnan, 2000). It is therefore not surprising that several international development organizations have strengthened the emphasis on gender in their development strategies in recent decades (see e.g. UN Millennium Project, 2005; ADB, 2011) and promoted female access to productive resources (e.g. FAO, 2011a).

Interestingly, however, the literature has usually found women to be less productive than men in agriculture, for a variety of reasons which we will discuss in more detail below. This may pinpoint potential trade-offs and/or caveats for development practitioners exclusively targeting women. Interestingly, the literature tends to focus on crop production, and it is not clear whether these findings also extend to dairy and livestock production. This is important, nevertheless, as dairy and livestock production have so often been considered as a "female"

[2] Despite the substantial reduction of gender gaps in primary schooling, it remains pervasive at secondary and tertiary levels, especially in South Asia and SSA (World Bank, 2011).

[3] The Gender Inequality Index measures the extent of inequalities between men and women at a country-level and had an average level of 0.46 in 2011, ranging from 0.28 in Europe and Central Asia to nearly 0.58 in Sub-Saharan Africa (UNDP, 2011). It is a composite index of three dimensions of gender inequality: reproductive health, economic (labor force) participation, and empowerment - including post-primary educational attainment and parliamentary participation.

production activity, especially in South-Asia (Achaya and Huria, 1986; FAO, 2011b). Dairy farming requires less physical strength compared to crop farming, but is typically more labor-intensive. Moreover, dairy activities are usually based on the farm and women can carry them out without leaving the farm, as in many developing regions (including India), rural women prefer (and/or are preferred) not to work out-of-home. Even if women may be responsible for dairy production; they may not be in charge of every aspect of the productive process. For example, in Bangladesh, women usually take care of dairy production; but milk marketing largely remains masculine territory (Goetz and Gupta, 1996; Siddiquee and Southwood., 2011).

In this paper, we try to fill this gap by focusing on dairy productivity and exploring differences between households where men are the main decision-makers over dairy, and households where these decisions are made by women. Our empirical analysis draws on a unique micro-level dataset on 1000 rural households which was collected in 2010 in Andhra Pradesh, a state in the South of India.

As the largest milk-producing country in the world, India presents a particularly interesting case to study issues related to dairy production. India is also an interesting region to study gender issues, given its historical legacy of discrimination against women.[4] Moreover, dairy is considered an important income source for rural women in India (e.g. Achaya and Huria, 1986), which is why governments and NGOs have often promoted dairy development as a strategy for female empowerment in rural areas.

This paper is structured as follows. Section 2 starts with a review of the relevant literature on gender and agricultural productivity. Section 3 describes the dataset used for the empirical analysis, and Section 4 discusses the setting of our study using descriptive statistics. Section 5 and 6 present our empirical methodology and the results of our analysis. Section 7 concludes.

[4] A striking example of discrimination against women is the phenomenon of "missing women", as first described by Amartya Sen in 1990 (Sen, 1990). It is estimated that in 2008, 3.9 million women - of which 22% in India - went missing (World Bank, 2011).

2. Gender and agricultural productivity

In order to sustain livelihoods and enhance food security in many poor regions, increasing agricultural productivity is of major importance. This holds especially in India, where the majority of poor people live in rural areas and largely depend on agriculture for a living.

Traditionally, development policy makers and practitioners have regarded women as less efficient crop producers (World Bank, 2001; Quisumbing, 1994). Several authors have found evidence for a gender gap in agricultural productivity. For example, a study of gender-based productivity differentials in Nepal finds that male labor is more productive in agriculture than female labor (Thapa, 2009). Peterman et al. (2011) find persistent lower crop productivity on female-owned plots in Nigeria and Uganda.

Many of these studies however ignore crucial variables, such as the quality of land and of inputs used. This may be important, for example, if men assign the most productive plots to themselves (Quisumbing, 1996), or if men have better access to commercial inputs.[5] Moreover, they often compare male-headed and female-headed households; of which the latter may be widowed, and by consequence comparatively income-poor and disadvantaged with regard to access to inputs (Quisumbing et al., 2002).[6] Uncertainty over land property rights may as well be an issue, as in many countries, inheritance rights are substantially weaker for women (e.g. Htun and Weldon, 2011).

Studies who control for these issues find, in general, that the gender gap in agricultural yields is mostly not due to the fact that women are worse farmers than men, but rather from gender-based differences in access to input and output markets, or lower bargaining power in these markets (Quisumbing, 1996; Rozelle et al., 2006; Croppenstedt et al., 2013). An analysis

[5] For example, in his study on Nepal, Thapa (2009) finds that male-managed farms use more commercial inputs.

[6] In our study, most households comprise both female and male adult members.

of the differences in agricultural productivity between male- and female-managed plots in Malawi by Kilic et al. (2013) shows that at low levels of productivity, differences are predominantly explained by gender disparities in access to inputs and asset ownership, while at higher productivity levels, gender differences in returns to the same set of observables become more important. A recent study by Handschuch and Wollni (2013) indicates that women receive lower prices in marketing of finger millet than men (at least if they market individually, rather than collectively), suggesting reduced access to output markets.

As a result of all these factors, women are indeed likely to achieve lower efficiency in crop production as well as agricultural commercial activities than men. To the best of our knowledge, no similar study has been conducted on the impact of gender on productivity in dairy.

3. Data

The dataset we use for our analysis was collected in 2010 in Andhra Pradesh, a state in the South of India. The region covering Rayalaseema (in particular, the districts Kurnool, Cuddapah, Ananthapur, and Chittoor) and the Southern part of Coastal Andhra (more specifically the districts Nellore, Prakasam, Guntur, and Krishna) was first subdivided into four subregions, based on climatic and dairy production system characteristics. In each of these subregions, one district was selected at random for inclusion in our sample. In the four selected districts, 50 villages were randomly selected. In a next step, 20 households from each village were selected using a stratified random sampling strategy and interviewed. The survey provides extensive data on household and household member demographic characteristics, household economic activities (including detailed agricultural production data) and data on intra-household decision-making over agricultural production activities (Squicciarini and Vandeplas,

2011). In our analysis, as our focus is on dairy productivity, we only focus on the subsample of 800 households which are engaged in dairy production.

4. Descriptive statistics

As in most of India, dairy production in Andhra Pradesh is largely dominated by rural farm households who derive most of their income from crop farming, and keep a few cows or buffaloes on the side. Milk is used primarily for own consumption within the household, but the surplus is sold (in very small volumes) to small itinerant milk traders or local milk collection centers in the village.[7]

Table 1 presents the summary statistics of the population under study, using appropriate sample weights to correct for oversampling of specific household categories during data collection. We restrict the survey sample to households with at least one dairy animal, which leaves us with 800 observations. In addition, observations are dropped if one of the variables in our analysis has a missing value, leading to a final sample size of 650 observations. Throughout our analysis, we will often refer to a male household head as the "husband" and to the wife of the household head or a female household head as the "wife" for improved readability.

The average household in our study is headed by a man of 47 years old, with 3.4 years of education. The wife is 41 years on average, and received 1.7 years of education. Hence, apart from the significant gap in age, we find a significant gender gap in education. The wife's mother received on average 0.12 years of education, indicating that female education has improved somewhat over time. 83% of the households adhere to Hindu belief, 12% to Christian, and 5% to Islam. 37% of the households belong to a general (or a "higher") caste; 22% of the households

[7] See Squicciarini and Vandeplas (2011) for more details.

belong to a scheduled tribe (ST) or scheduled caste (SC) and 41% belong to the class of other backward castes (OBC).[8]

The households in the population under study own on average 1.5 ha of land. Average wealth of households is also reflected in an asset index, which varies between -1.4 and 10.7. This index is calculated through factor analysis based on ownership of a list of "large" assets such as diesel engines, pickups, or cars as well as "small" assets such as fridges, bicycles, and mobile phones (Squicciarini et al., 2013).[9] In 37% of the households, the wife receives a wage income, indicating that she participates in off-farm employment.

Those households participating in dairy activities own on average 2.6 female adult dairy animals (comprising both cows and buffaloes) – reflecting the small scale of typical dairy production systems in the region. These dairy animals can either be traditional, "desi" breeds, which tend to be fairly well adapted to local environmental conditions, or crossbreds, which have some "exotic" genetic content and (usually) higher dairy yields. In our analysis, we will use the share of crossbred animals to local breeds as an indicator of the "technology level" of a dairy production system. In the population under study, this share is 32% on average. 6% of the households use commercial cattle feed mix; other households may feed their animals other types of concentrate feed, possibly from own production. Households spend on average 35.2 minutes per animal per day on milking and washing the animals.[10]

The resulting average yield is 809 L per cow per year, which is less than 1/7 of yields generally obtained in developed countries. This yield is calculated as the average yearly yield

[8] Scheduled castes (SC) and scheduled tribes (ST) are castes which historically have experienced social discrimination in India. They respectively represent 16.2% and 8.2% of the total Indian population (Census of India, 2011) and benefit from different types of affirmative action policies. These castes broadly correspond to the populations formerly referred to as "dalits" and "adivasis". In this paper, we will refer to members of SC and ST as "SC/ST". Other backward castes (OBC) are castes which faced less discrimination than SC and ST, but are considered by the government to be "sufficiently" economically disadvantaged to also deserve affirmative action policies in education and public employment (Census of India, 2011). Most families in this category historically belonged to the "shudra" caste of unskilled workers.

[9] The asset index is a relative measure of asset ownership rather than an absolute one. In the original dataset of 1000 households, the asset index has been centered around 0, with a variance of 1 (Squicciarini et al., 2013).

[10] Time for feeding is much more variable and harder to measure, as some households stallfeed their animals, some let their animals graze, and sometimes grazing is outsourced to other persons, who take care of animals from different owners at the same time.

in milk production by household *i*, over the 12 months prior to the survey (July 2009 to June 2010), divided by the number of female adult dairy animals. For the purpose of our analysis, we will take the log of this number; which has an average value of 6.41.

As involvement in dairy activities could be influenced by what men and women experienced and learned at home before marriage, we also consider whether the husband's and the wife's parents engaged in milk production and selling activities. 70% of the household heads in our study had parents which produced milk, and for 59%, these were also selling (part of) their milk. The corresponding figures for their wives are respectively 62% en 49%. Not all milk producers are selling their milk; many consume all of it themselves, for instance because they have a larger family, less cows, or because their productivity is not high enough to generate a surplus.

In 15% of the households engaged in dairy, the wife is the primary decision maker in dairy production. This will be the key variable of interest in our analysis later on. We will now explore to what extent women who are "responsible" for dairy production and/or their households differ from those who are not considered "responsible", even if they may be strongly involved in daily management of dairy production activities.

Table 2 shows descriptive statistics for households where, respectively, the husband and wife decide over dairy production. It also indicates whether these differences are statistically significant. A first observation is that households where the wife decides are, on average, slightly older, and slightly less educated than households where the husband decides. Age and education may be correlated; as younger generations tend to have higher levels of schooling in general. Only the difference in the wife's education level is significant, however. Interestingly, in those cases where the wife is responsible, her mother received on average more education; although the difference is not statistically significant. Households where the wife decides have less children at home; and this difference is statistically significant. It could be related to the

fact that households are slightly older; but also that with less children, women may have more time to spend on dairy activities.

Households that adhere to Christian belief, and households that are members of SC/ST castes are more likely to give responsibility for dairy activities to the wife. Members of OBC castes are significantly less likely to do so.

Households where the wife decides have more land and a higher value of the asset index; but none of these differences are statistically significant. Women who decide are more likely to gain off-farm wage income; but this difference is not significant either.

If we look at differences in dairy production system characteristics, we find that husbands are more likely to decide in those households with more dairy animals (even if the difference is not statistically significant), with a greater share of crossbred animals, and with a higher (albeit not significantly so) labor input into dairy production. Still, they seem to achieve lower yields; although the difference is not statistically significant. This is striking, especially given the fact that they tend to use better technology. Figure 1 presents this result graphically: households where the wife decides over dairy (dotted line) display a higher expected yield compared to households where the husband decides (dotted line). This may mean that women take better care of the dairy animals if they are in charge, or follow-up on production variables more closely – or differently.[11] There is no evidence that they are more likely to spend more hours on taking care of the dairy animals if they are in charge.

Finally, in households where selling milk runs in the family (that is, where the husband's or the wife's parents were also selling milk) are more likely to leave the responsibility for dairy-related decisions to the wife.

[11] Along these lines, Qian (2008) argues that women are more productive in tea production because they are more careful in picking the tea leaves.

These results are of course merely descriptive; to disentangle the effects of different variables, regression analysis is needed. This is what we will do in the next step.

5. Empirical methodology

We can measure the impact of female decision-making power on our outcome variable (the log of yearly milk yields per animal) through a simple OLS regression, with the following specification:

$$Yield_i = \alpha_{1i} + \beta_1 * female\ decision\ power_i + \gamma_1 * socio\text{-}demographic\ variables + \delta_1 * cultural\ variables + \lambda_1 * wealth\text{-}related\ variables + \eta_1 * dairy\text{-}related\ variables + \mu_{1i} + \varepsilon_i \quad (1)$$

We control for a range of different variables which may affect yields: first, as socio-demographic variables, we include age and education variables for the husband and his wife. These may reflect experience and cognitive skills which might be important for determining productivity. Next, we control for cultural variables (a dummy for Christian religion, a dummy for membership of an SC/ST caste; and a dummy for membership of an OBC caste). These may proxy behaviors and norms, social networks which might be important for determining productivity, or possible discrimination in access to credit and input markets.

We also control for wealth, by including a measure for land ownership and an asset index. Wealth is likely to be correlated with productivity, either as a cause (e.g. as it may promote access to input and credit markets) or as a result (as higher productivity will generally lead to increased incomes).

As for dairy-related variables, the number of female adult dairy animals is included, as well as a dummy reflecting whether the parents of the decision-maker (be it the husband or the wife) used to produce or sell milk before. This dummy combines information from the four dummies relating to parental activity discussed in Table 1 and Table 2 with information on who is deciding on dairy production. It controls for the potential impact of intergenerational learning:

if the decision-maker saw his/her parents taking care of dairy; he/she might have learned from them and even trained his/her own skills at home.

As the existing literature points out that gender differences in productivity may disappear once one controls for the quality of inputs or the used production technology; we show how our results change when we introduce a set of three indicators reflecting dairy production technology: the share of crossbred dairy animals in the household's herd; whether the household feeds the animals with commercial concentrate feed; and the labor inputs used for milking and washing dairy animals. Finally, we include district-level effects to control for local conditions which may be relevant in the determination of yields (μ); and ε is the idiosyncratic error term. All regressions in this paper feature error terms clustered at the village level.

The OLS results could be biased, however, in case there are unobserved variables which increase (or reduce) the likelihood that the wife decides; and simultaneously have an impact on yields. Perhaps men who know their wife is good at taking care of dairy animals, are more likely to give here responsibility?

Hence, we check our results using a two-stage instrumental variables regression strategy, which controls for potential endogeneity of the decision to assign responsibility over dairy to the wife. In a first stage, we estimate the likelihood that a woman is taking decisions over dairy production based on a set of exogenous variables and a set of control variables. In a second stage, we use this predicted likelihood as a proxy for female decision-making power to estimate the impact of female decision-making power on our outcome variable, yearly milk yields.

Our first stage regression takes the following form:

$$\textit{Female decision power}_i = \alpha_{2i} + \gamma_2 * \textit{socio-demographic variables} + \delta_2 * \textit{cultural variables} + \lambda_2 * \textit{wealth-related variables} + \eta_2 * \textit{dairy-related variables} + \mu_{2i} + \varepsilon_i \quad (2)$$

This equation is estimated using limited information maximum likelihood, as it is preferred to two stage least squares for small sample sizes. The dependent variable is a binary variable reflecting female decision-making power which takes the value 1 if the wife takes production-related decisions in dairy, and 0 if her husband does. As explanatory variables, we include a range of socio-demographic variables, notably the age of the husband and his wife and their respective education levels. The literature suggests that a woman's age, the age difference between her and her husband, and marital duration are determinants of her intra-household bargaining power (Gupta, 1995; Dito, 2011). Agenor and Canuto (2013) assume relative bargaining power of women to be a function of her education level relative to her husband's, e.g. because education exposes a women to ideas that promote her independence by increasing her access to resources and by widening her employment opportunities (Malhotra and Mather, 1997).

We also include the education level of the wife's mother. We hypothesize the former is a proxy for the wife's mother's intrahousehold bargaining status, which might affect the wife's own bargaining status through learning effects. As education was not very common for rural women of previous generations in India, one could consider the ones who did receive a noteworthy education as particularly privileged and attribute this to the fact that they are stemming from a family with more attention for girls' education, which might be related to a stronger empowerment of women in the household. The number of children of the husband and his wife which still live at home also enters as an explanatory variable. This has been named in the literature as having an important effect on a wife's bargaining power (Schuler et al., 1996; Dito, 2011). However, it could also be an indicator of the wife's opportunity cost of time: with more children, she might have less time to spend on dairy activities.

As for cultural variables, we include a religion dummy taking the value of one for Christians and zero for Hindus and Muslims;[12] a dummy variable SC/ST reflecting whether a household belongs to a scheduled caste or tribe; and a dummy *OBC* which indicates whether the household belongs to an "Other Backward Caste". While some have argued that gender biases in intra-household bargaining power reflect innate differences in personality traits between men and women (for example because men are better equipped to compete, see Lawrence (2006)), research has shown that nurture also matters. A study by Gneezy et al. (2009) reveals that in a matrilineal society (such as the Khasi in India), women show stronger competitive behavior than men – in contrast with patrilineal societies (such as the Maasai in Kenya), where men compete more. Morgan and Niraula (1995) show that the nature of patriarchy and the caste-system contribute to a woman's status and autonomy. This confirms the importance of social and cultural background for gender-related behavior. In India, important determinants of female bargaining power may therefore include religion and caste. Although most authors agree on the important influence religion has throughout cultures and societies, the findings on the religion-power relationship have been ambiguous or contradictory (Morgan et al., 2002; Jejeebhoy and Sathar, 2001). Interestingly, Luke (2013) finds that higher caste women tend to support male authority more than lower caste women in India.

Our wealth variables include the amount of land owned, an asset index reflecting asset ownership, and a dummy *wage income* that takes the value one if the woman earns an income off-farm. This may reflect her opportunity cost of labor. It may as well correlate with intra-household bargaining power, especially if employment is away from home (e.g. Anderson and Eswaran, 2007; Yusof and Duasa, 2010).

As for dairy-related variables, we control for the number of female adult dairy animals, the type of technology the household uses in dairy production (more specifically, the share of

[12] The low number of observations does not allow us to control separately for muslim religion.

crossbred animals; whether commercial concentrate feed is used; and the amount of labor that goes into washing and milking the animals on a daily basis). We also control for the husband's and the wife's parents' involvement in milk production and selling, through four different dummies. Possibly, if the wife's parents were productive enough to generate a surplus of milk to be sold later on, they had strong production knowledge which could have been passed on to their daughter, making it more likely that the latter will be allowed to take production decisions during her adult life. On the other hand, families which were only producing but not selling milk, might have been less efficient at dairy farming, limiting (the appeal of) potential intergenerational learning effects.

Finally, as above, we include district dummies to pick up potentially relevant spatial effects.

Those variables who are hypothesized to be relevant to determine the wife's decision power; but not dairy yield, will be used as exogenous variables in our instrumental variable regression: the education level of the wife's mother; the fact whether she has a wage income off-farm; and the number of children which still reside at home.

We estimate this model using a Probit model; and then we cross-check its results using a linear probability model. We will then use these results to control for potential endogeneity of the intrahousehold decision process on whom to assign responsibility over dairy production to.

6. Results and discussion

Table 3 presents the results of the OLS regressions, first without (regression model 1) and then with controls for dairy production technology (regression model 2). The first regression shows that our variable of interest, whether the wife decides over dairy, is positive but insignificant.

On the other hand, a higher education level of the wife does increase dairy yields significantly. This is as we expected and suggests that cognitive skills support dairy productivity.

Of the cultural variables included, only the dummy for OBC membership is significant, and negative in sign. A potential explanation is discrimination in access to input markets; but as we mentioned before, there could be other reasons as well.[13] If disparities in yield are due to unequal access to markets, however, this is a reason for concern and an important message to Indian policymakers. Our results add to an earlier study by Vandeplas et al. (2013) on the dairy sector in the North of India which finds a significant impact of low caste status on dairy profitability.

We find a negative (but insignificant) correlation with land ownership and a positive significant correlation with asset ownership. The latter confirms our expectations and may point at a positive impact of wealth on access to inputs or credit; or, conversely, the fact that higher yields enhance the accumulation of assets.

Livestock herd size has a negative effect, which suggests that households with smaller dairy production activities are better able to focus resources on the few dairy animals they have and as such achieve higher yields. It is not uncommon in the literature to find an inverse relationship between farm size and yield (e.g. Sen, 1966; Larson et al., 2014). Interestingly, the results suggest that if the decision-maker over dairy production has parents who were producing milk, dairy yields are smaller in general; while if he/she has parents who used to sell milk, dairy yields are larger in general. Caution is due in interpreting these results. One should not forget that if parents were selling milk, they must have been producing it as well. Hence, the real impact of having parents who were producing milk is obtained by summing the coefficient on

[13] There is some multicollinearity between our dummy for Christian religion and our dummy for SCST caste status. The historical reason is that to escape social stigma, many SCSTs have converted to Christianity in the past. If we drop the dummy for Christian religion, the negative coefficient on SCST would be significant at a 15% significance level.

the parental production and the parental sales dummies. As the latter is larger than the former, the real impact of parental production is positive. The real takeaway is that, if parents were producing milk, but not selling it, they were probably not sufficiently productive to generate a marketable surplus; and it is not surprising that in this case, intergenerational transfer of skills is less fruitful.

When we introduce the technology variables (regression model (2) in Table 3), the model fit improves sizably. All coefficients on technology variables have the expected sign (positive impact on yields), they are large in magnitude, and strongly significant. Interestingly, this makes the coefficient on our variable of interest go up. By controling for the fact that women usually take care of production systems which are less technologically advanced; we find that female decision-making does have a positive significant impact on yields. The magnitude of the coefficient suggests that if the wife is responsible, yields are 15% higher than if her husband is responsible for dairy production.[14]

Coefficients on other variables remain largely similar. There is a slight shift in significance between the socio-demographic variables; but coefficients largely retain the same magnitude, suggesting that the younger the husband is, and the older his wife; and the less education the husband has and the more his wife has, the higher yields are. As husbands in our sample are usually older (on average 6.4 years) and more educated (on average 1.7 years more), a potential interpretation is that yields are higher if there is a smaller gap in age and/or education between the husband and his wife. Age and educational differences between marriage partners have been related to female bargaining power in the literature (Das Gupta, 1995; Malhotra and Mater, 1997; Dito, 2011; Agenor and Canuto, 2013). Note that, if these gaps would be

[14] Given our log-linear specification, the impact of *femdecd* switching from 0 to 1 on yield is $(e^{\beta} - 1)*100$. This can be approximated by $\beta*100$ at lower levels of β. If we do not use this simplification, the impact amounts to 16%.

negatively correlated with female decision power; they would result in a downward bias on the impact of female decision-power.

Coefficients on other variables (cultural as well as wealth- and dairy-related variables) are robust in magnitude, direction, and significance.

However, as we said before, these OLS results could be biased. Therefore, we corroborate our results using an instrumental variable strategy in addition. This implies that we first model the determinants of the decision to assign bargaining power to the wife; and in a next step we use this process for the first stage of our two-stage regression methodology.

Table 4 shows the results of the linear probability model and probit regressions assessing the determinants of female decision power. As explained before in Section 5, we use largely the same explanatory variables as before; but we add a few which will act as exogenous instruments in a next step: the education level of the wife's mother; the number of children of the husband and his wife who still live at home; and whether the wife has some wage income. Moreover, the variables on whether the husband's and the wife's parents were involved in producing and/or selling milk enter separately into this regression, in contrast with the yield regression discussed above.

The marginal effects from the OLS regression (column 1) and from the probit regression (column 3) are markedly similar, which confirms the robustness of our regression. Somewhat to our surprise, we find that the wife's education level makes it less likely that she decides over dairy. Maybe this points at the impact of her opportunity cost of time; in the sense that more educated women are more likely to engage in other types of activities. The education level of her mother does have a positive impact on the likelihood that the wife may decide over dairy, as we expected. The fact that having more children at home also reduces the likelihood that a woman decides over dairy supports our hypothesis on the wife's opportunity cost of time.

Having more assets increases the likelihood that the wife decides over dairy. Having a wage income does so as well; but the impact is not significant.

Finally, when we look at dairy-related variables, we mainly find that women are less likely to decide over dairy animals when farm technology is more advanced (more crossbred animal types).[15] Women are more likely to decide if their parents used to not only produce, but also sell milk. If their parents were producing, but not selling milk, they are actually less likely to take dairy-related decisions. In the probit regression, which has the best model fit, the latter two effects tend to cancel each other out – which means there is no remaining effect of parental involvement in dairy production and sales on the wife's decision power in dairy.

Next, we use these results for the first stage of our two-stage instrumental variable regression with outcome variable yield. Model (3) (Table 3) shows the regression without, and model (4) with inclusion of dairy technology variables. Again, the model which includes dairy technology variables performs better than the one without.

The results are also broadly equivalent to the OLS results; with one exception; which is our variable of interest. The coefficient on our variable of interest is still positive, and much larger in magnitude, but no longer significant, as a result of very large standard errors. A potential reason may be that our instrumental variables are marginally weak.[16]

To explore whether the IV results are preferred to the OLS result, we do a simple test for endogeneity by including the residuals from our stage 1 regression in the stage 2 (OLS) regression. This test shows that the residuals do not have a significant effect on yields; and hence suggests that we need not treat female decision-making power as endogenous.

[15] There could be reverse causality at play here.

[16] That is, depending on the criterion used, they are classified as weak, or not weak.

7. Conclusion

Many studies have found a "gender gap" in agricultural productivity (Croppenstedt et al., 2013). This gender gap is often attributed to unequal access to productive resources, technology, and input and output markets. The existing literature has mostly focused on female productivity in crop production.

Based on household-level data from Andhra Pradesh (India), this paper looks at female productivity in dairy production, where female involvement is usually higher than in crop production. We find that, if we do not control for dairy technology, gender has a positive, albeit insignificant impact on dairy productivity. However, when we do control for dairy technology, the coefficient on gender increases and becomes significant at the 10% level. Our results suggest that, as in crop farming, women tend to use less technologically advanced production methods than men if they are allowed to decide. However, in contrast with crop farming, women do seem to achieve better yields than men despite their technological disadvantage. It tentative explanation is that women might take better care of the dairy animals, or follow-up on production more closely – or differently.

Our paper adds nuance to the traditional view in the literature that women are less productive in agriculture than men, by showing that this observation is product-specific and depends on the type of labor requirements involved. Investigating in more detail differences in production practices provides an interesting venue for future research. Hence, while further research is needed, our results may imply that if men delegate control over dairy production to women – especially in those cases where women are already exerting most of the effort in terms of labor hours – better development outcomes may be obtained.

A word of caution is due, however, in the interpretation of our results. As we discussed in Section 4, dairy production in Andhra Pradesh is generally still very inefficient according to international standards; with yields in our sample averaging 809 L per dairy animal per year. In

general, technology used in the dairy sector is still very basic. Most cattle are fed with grasses collected from sideways or with leftovers after the crop harvest, and development of formal input markets is weak. Hence, it is not clear how our results will change with further development of the dairy sector in India.

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Figure 1: Probability distribution for yields, according to gender of decision maker

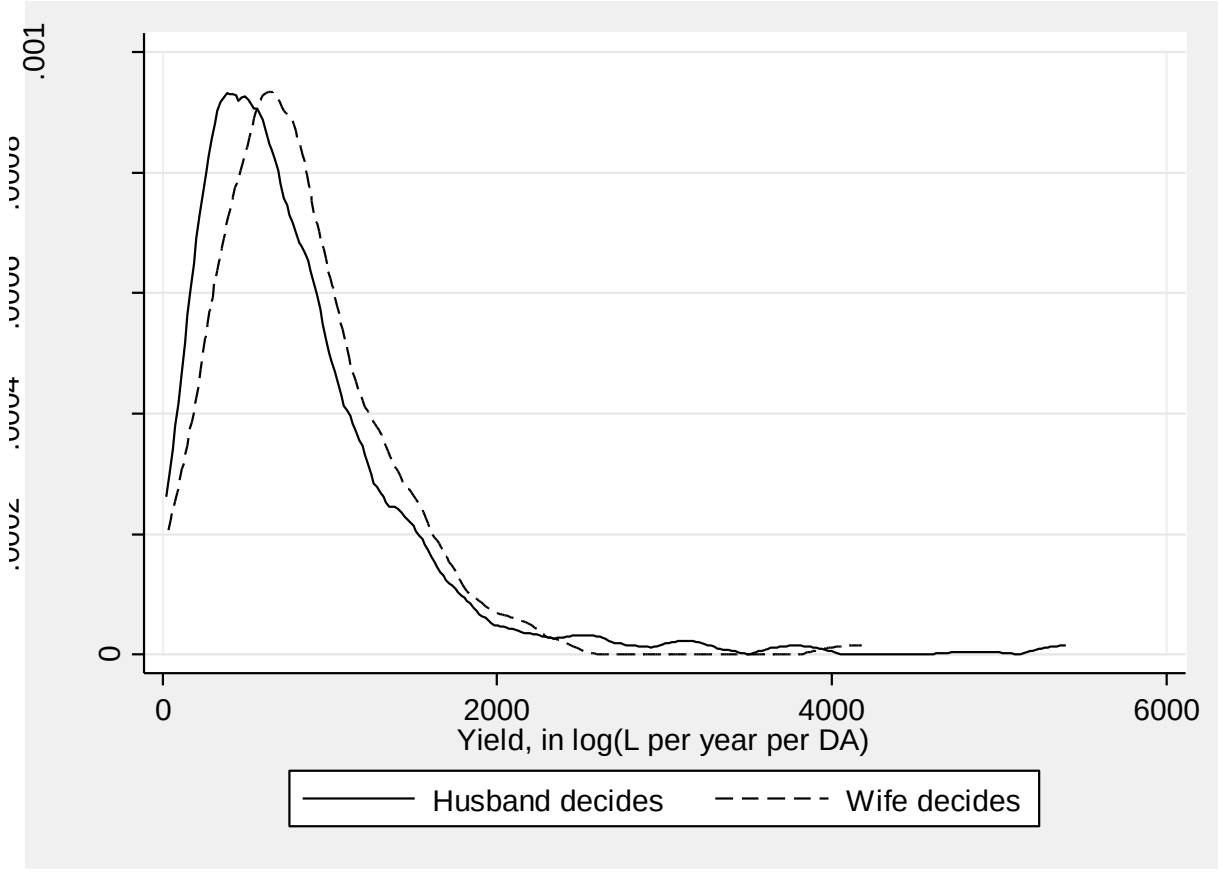

Table 1: Descriptive statistics

Variables	Unit	Mean	St. Dev.	Min	Max
Sociodemographic variables					
Age husband	years	47.4	11.1	23.0	82.0
Age wife	years	41.0	10.5	19.0	110.0
Education level husband	years	3.4	4.6	0.0	18.0
Education level wife	years	1.7	3.2	0.0	15.0
Education level maternal mother	years	0.1	0.9	0.0	10.0
Number of children		2.0	1.1	0.0	8.0
Cultural variables					
Christian	%	12%			
SC/ST	%	22%			
OBC	%	41%			
Wealth-related variables					
Land owned	ha	1.5	2.6	0.0	30.0
Asset index		0.0	1.0	-1.4	10.7
Wife has wage income	%	37%			
Dairy-related variables					
Livestock herd size	nr DA	2.6	1.9	1.0	17.0
Ratio crossbred/all animals		0.32	0.45	0.00	1.00
Commercial concentrate feed	1 if yes	6%			
Labor input (milking & washing)	min/DA day	35.2	25.0	0.0	240.0
Yield (year average)	log(L/DA year)	6.4	0.8	3.1	8.6
Wife decides over dairy	1 if yes	15%			
Parents husband producing milk	1 if yes	70%			
Parents husband selling milk		59%			
Parents wife producing milk		62%			
Parents wife selling milk		49%			
District dummies					
Chittoor	%	11%			
Cuddapah	%	17%			
Kurnool	%	34%			
Guntur	%	37%			
Nr of observations		650			

Note: Figures reflect weighted averages.

Table 2: F-tests for differences between groups

Variables	Unit	Husband decides	Wife decides	F-test
Sociodemographic variables				
Age husband	years	47,20	48,70	1,19
Age wife	years	40,80	42,20	1,44
Education level husband	years	3,49	2,67	1,75
Education level wife	years	1,76	1,02	4,60 **
Education level maternal mother	years	0,08	0,34	1,58
Number of children at home		2,08	1,81	3,80 *
Cultural variables				
Christian	%	10,30	18,70	2,92 *
SC/ST	%	21,00	27,40	1,24
OBC	%	42,60	31,30	3,27 *
Wealth-related variables				
Land owned	ha	1,45	1,96	0,83
Asset index		0,00	0,23	2,26
Wife has wage income	%	35,60	43,60	1,46
Dairy-related variables				
Livestock herd size	nr DA	2,63	2,44	1,13
Type of breeds	% crossbred	0,34	0,20	8,06 ***
Commercial concentrate feed	1 if yes	0,05	0,12	2,43
Labor input (milking & washing)	min/DA day	35,22	34,75	0,01
Yield (year average)	L/DA day	6,40	6,53	1,90
Parents husband producing milk	%	69,03	74,67	0,99
Parents husband selling milk	%	56,55	70,93	5,96 **
Parents wife producing milk	%	61,64	66,64	0,67
Parents wife selling milk	%	46,73	63,63	7,36 ***
Number of observations		564	86	

Note: Figures reflect weighted averages.

Table 3: Determinants of yields

	(1) OLS w/o tech		(2) OLS w tech		(3) IV w tech	
	coef	**se**	**coef**	**se**	**coef**	**se**
Wife decides over dairy	0.10	0.09	0.15 *	0.08	0.40	0.55
Sociodemographic variables						
Age husband	-0.01	0.01	-0.01 *	0.01	-0.01 *	0.01
Age wife	0.01	0.01	0.01 *	0.01	0.01	0.01
Education level husband	-0.01	0.01	-0.02 **	0.01	-0.01 *	0.01
Education level wife	0.02 *	0.01	0.02	0.01	0.02 *	0.01
Cultural variables						
Christian	-0.06	0.15	-0.06	0.12	-0.09	0.11
SC/ST	-0.07	0.15	-0.13	0.14	-0.14	0.14
OBC	-0.11 *	0.06	-0.12 *	0.07	-0.11	0.07
Wealth-related variables						
Land owned	-0.11	0.07	-0.04	0.07	-0.04	0.07
Asset index	0.13 ***	0.04	0.12 ***	0.03	0.11 ***	0.04
Dairy-related variables						
Livestock herd size	-0.09 ***	0.02	-0.05 ***	0.02	-0.05 ***	0.02
Parents dec-maker producing milk	-0.32 ***	0.12	-0.34 ***	0.11	-0.32 ***	0.10
Parents dec-maker selling milk	0.53 ***	0.10	0.45 ***	0.09	0.43 ***	0.09
Dairy technology						
Type of breeds			0.42 ***	0.09	0.45 ***	0.12
Commercial concentrate feed			0.19 **	0.08	0.17 **	0.09
Labor input (milking & washing)			0.26 ***	0.08	0.26 ***	0.08
District dummies						
Cuddapah	-0.23 *	0.14	-0.10	0.11	-0.09	0.10
Kurnool	-0.35 **	0.16	-0.23	0.14	-0.23 *	0.13
Guntur	0.11	0.13	0.03	0.10	0.02	0.11
Constant term	6.87 ***	0.20	5.87 ***	0.35	5.83 ***	0.36
Number of observations	650		650		650	
Adjusted/Pseudo R2	0.28		0.35		0.34	

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 4: Female decision power (production) and household characteristics

	OLS		Probit		Probit Marg. Eff.	
	Coeff.	**S.E.**	**Coeff.**	**S.E.**	**Coeff.**	**S.E.**
Sociodemographic variables						
Age husband	0,00	0,00	0,01	0,01	0,00	0,00
Age wife	-0,00	0,00	-0,01	0,01	-0,00	0,00
Education level husband	-0,00	0,00	-0,03	0,02	-0,00	0,00
Education level wife	-0,01 **	0,00	-0,06 ***	0,02	-0,01 **	0,00
Education level maternal mother	0,05 **	0,02	0,24 ***	0,07	0,04 ***	0,01
Number of children at home	-0,02 **	0,01	-0,13 **	0,06	-0,02 **	0,01
Cultural variables						
Christian	0,10	0,07	0,44 *	0,28	0,10	0,07
SC/ST	0,07	0,05	0,40	0,26	0,08	0,06
OBC	-0,02	0,03	-0,05	0,19	-0,01	0,03
Wealth-related variables						
Land owned	0,02	0,02	0,09	0,10	0,02	0,02
Asset index	0,04 **	0,02	0,18 ***	0,06	0,03 ***	0,01
Wife has wage income	0,05	0,03	0,24	0,16	0,04	0,03
Dairy-related variables						
Livestock herd size	-0,01	0,01	-0,04	0,05	-0,01	0,01
Type of breeds	-0,13 ***	0,04	-0,67 ***	0,24	-0,12 ***	0,04
Commercial concentrate feed	0,05	0,05	0,21	0,19	0,04	0,04
Labor input (milking & washing)	-0,02	0,02	-0,09	0,11	-0,02	0,02
Parents husband producing milk	0,05	0,04	0,26	0,28	0,04	0,04
Parents husband selling milk	-0,00	0,04	-0,02	0,25	-0,00	0,04
Parents wife producing milk	-0,10 **	0,04	-0,63 **	0,26	-0,12 **	0,06
Parents wife selling milk	0,12 ***	0,04	0,68 **	0,26	0,12 **	0,05
District dummies						
Cuddapah	-0,02	0,04	-0,03	0,28	-0,01	0,05
Kurnool	0,02	0,04	0,20	0,26	0,04	0,05
Guntur	0,05	0,04	0,33	0,27	0,06	0,06
Constant term	0,23 *	0,13	-0,82	0,68		
Number of observations	650		650			
Adjusted/Pseudo R2	0,070		0,136			

Note: *** p<0.01, ** p<0.05, * p<0.1